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SOIL MANAGEMENT EXPERIMENTS

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GENERAL PLAN OF THE FIELD EXPERIMENTS

Series 100	Series 200	Series 300	Series 400
101 M	201 M	301 M	401 M
102 None	202 None	302 None	402 None
103 ML	203 ML	303 ML	403 ML
104 M	204 M	304 M	404 M
105 MP	205 MP	305 MP	405 MP
106 MRP	206 MRP	306 MRP	406 MRP
107 M	207 M	307 M	407 M
108 MPK	208 MPK	308 MPK	408 MPK
109 MRPK	209 MRPK	309 MRPK	409 MRPK
110 M	210 M	310 M	410 M
111 MLP	211 MLP	311 MLP	411 MLP
112 MLRP	212 MLRP	312 MLRP	412 MLRP
113 M	213 M	313 M	413 M
114 MLPK	214 MLPK	314 MLPK	414 MLPK
115 MLRPK	215 MLRPK	315 MLRPK	415 MLRPK
116 M	216 M	316 M	416 M

M = manure; L = limestone; P = superphosphate; RP = rock phosphate; K = potash.

BULLETIN NO. 397

Soil Management Experiments

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GENERAL PLAN OF THE EXPERIMENTS

The diagram on the opposite page shows in a general way how plots were used for the field experiments reported in this bulletin. The four similarly treated series of plots shown on the diagram provide for growing all the crops in a four-year rotation, each year. If, for example, the rotation is corn, wheat, and two years of mixed clover and grass hay, and corn should appear on Series 100, then second-year hay would appear on Series 200, first-year hay on Series 300, and wheat on Series 400. The next year the crops would all move forward one series, wheat going to Series 100.

In an experiment of this type the object is to determine the effect on crops, of limestone and various fertilizers when manure is returned to the plots equal to the weight of the crops they produce, wheat grain excepted. Thus check plots (Nos. 1, 4, 7, etc.) would receive considerably less manure than the fertilized plots that produce larger yields. Some of the experiments reported in this bulletin vary somewhat from this general plan.

The plots used in the experiments reported in this bulletin range in size from 1/10 to 1/20 acre, most of them being of the larger size.

METHOD OF COMPUTING CROP INCREASES

It is practically impossible to find an area of soil of uniform productivity large enough for a field experiment; in fact it is rare that two adjoining plots have the same productivity. Because of lack of uniformity in soil, the use of check plots at regular intervals in a series of plots is necessary to measure crop increases. The older experiments did not have enough check

plots. The importance of preliminary cropping to determine soil variation and the importance of frequent check plots were not fully appreciated when the older experiments were started. The increases in yield resulting from the various treatments were calculated by comparison with the check plots.

In this report, where the number and location of check plots were sufficient, the crop increases were computed upon the assumption that the soil varied uniformly from one check plot to another, before the plots were treated. This method may be illustrated by the following example.

Plot number	Treatment	Yield of corn per acre	Increase
1	None (check plot)	30 bushels	.....
2	Superphosphate	38 bushels (–31)	7 bushels
3	Limestone and superphosphate	45 bushels (–32)	13 bushels
4	None (check plot)	33 bushels	.....

Upon the assumption of uniform variation in the soil between the two check plots, plot 2, if untreated, would have yielded 31 bushels per acre, and plot 3, 32 bushels per acre. Subtracting assumed yields from the respective yields of the treated plots, gives increases of 7 bushels and 13 bushels. While absolutely uniform variation does not often occur, this seems, on the whole, to be the most satisfactory method of computing increases. However, other methods may be used. The increase may be calculated by subtracting from the yield of a treated plot that of the nearest check; or the average yield of two checks between which a treated plot lies may be subtracted from that of the treated plot. Two adjacent plots differing in treatment by a single element may be compared directly, without reference to a check plot.

If there is not substantial agreement in increases computed by all these methods, they are not considered significant. To be considered significant, the increase or decrease in yield of a treated plot should be greater than the difference in yield of the check plots between which the treated plot lies.

In most of the experiments reported in this bulletin, manure, where used, was applied on both check plots and fertilized plots; therefore the calculated increases are accredited to the limestone

and fertilizers used on the treated plots. If check plots are not treated in any way, they may reach such a low state of productivity that they give an exaggerated importance to soil treatments as measured by crop increases. In such instances there may be a large increase due to fertilizer treatment when the total production is not high enough to cover the cost of production.

FERTILIZING MATERIALS USED

Unless otherwise specified, the following grades of fertilizing materials were used.

Superphosphate containing 16 percent "available" phosphoric acid. In recent years 20 percent superphosphate was the lowest grade sold in Kentucky. During this time 80 pounds of this grade was used as the equivalent of 100 pounds of 16 percent grade.

Rock phosphate containing approximately 28 to 32 percent total phosphoric acid and ground sufficiently fine for about 95 percent to pass thru a 100-mesh screen, unless otherwise specified. Rock phosphate was used at twice the rate of superphosphate in the earlier experiments for the reason that when the work was begun these rates represented approximately equal cost per acre. During the period of these experiments the prices of superphosphate and rock phosphate would have enabled the farmer to buy three to four pounds of phosphorus in rock phosphate for the cost of one pound of phosphorus in superphosphate. However, the availability of phosphorus in superphosphate is higher than in rock phosphate.

Potash salts, muriate or sulfate, containing approximately 50 percent potash (K_2O), except that for a short time during and following the war potassium carbonate was substituted.

Commercial nitrate of soda varying from approximately 15.5 to 16 percent nitrogen.

The manure used on the outlying experiment fields was obtained from miscellaneous sources and very probably was not so good as could have been produced by feeding the crops grown on the fields, which crops contained a large proportion of legumes. It is not feasible to keep livestock at these small fields for the purpose of producing manure. The manure was thoroly mixed before application to the plots.

METHOD OF REPORTING CROP YIELDS

The yields are all on the basis of field-cured crops, as facilities were not available for making accurate moisture determinations for the large number of plots involved. Seventy pounds of ear corn were allowed to the bushel. Efforts were always made to have crops as well cured as conditions would permit. Soybeans are difficult to cure and frequently are harvested late when weather for curing is unfavorable; consequently the soybean hay frequently contained considerable moisture.

Samples of corn and of mixed hay were taken for several years at the time the yield weighings were made. These samples were well air dried, and the loss of moisture determined. There was considerable variation by years and by plots the same year. The average loss on air drying was about 7 percent for ear corn and 10 percent for hay.

Crop failures are not included in the averages. Sometimes substitute crops were grown for harvest, but not always, because it was desired not to interrupt the regular rotation. However, in farm practice the use of substitute crops would be the logical procedure.

The actual differences in hay yields on the plots so treated as to produce good clover and the other treated plots and check plots that did not produce good clover were greater than the yield figures indicate, because where the clover was poor there was a larger content of weeds and wild grasses. This was especially true in the earlier years of the experiment when clover alone was used. Since Korean lespedeza was added to the mixture, the proportion of weeds has been much reduced on the plots that will not grow red clover.

Plots treated with limestone and phosphate usually have produced good clover, while plots without these treatments and the check plots often have produced low yields or none. The growth of a legume greatly influences the yield of non-leguminous crops in the rotation. It seemed poor practice to continue to use only clover which was sure to fail on many plots and to make poor growth on others, for to do so would give exaggerated importance to those soil treatments that produce good clover. For this reason it was decided to use a mixture of legumes and grasses for hay, except at Lexington.

Even under favorable soil conditions for clover, the use of a mixture of plants for hay is considered good practice, for often other than soil conditions cause a failure of clover when lespedeza or alfalfa, for example, persists and produces good yields. Grass in the mixture also aids in preventing leaching of nitrogen, particularly with lespedeza and red clover and, to some extent, alfalfa. Alfalfa in the mixture is valuable, for it often produces extra cuttings. Tho lespedeza may not get high enough to produce much hay, it may produce a dense growth which is valuable in preventing erosion and adding nitrogen to the soil.

In former reports only the first cutting of hay was reported. In this report all cuttings are included in the averages, except cuttings sometimes made on wheat land the year of harvest.

CROP AND FERTILIZER VALUES

No money values of soil treatments are given in this report. Costs of limestone and fertilizers and crop values vary greatly in different places and at different times. It seems better for those interested in net money values of crop increases to make their own calculations based upon local prices. The most profitable treatments are evident without such calculations. For the benefit of those who wish to make such calculations, the average yearly applications of fertilizers and limestone are given or clearly implied.

DISCONTINUED EXPERIMENTS

In this bulletin all the soil management experiments conducted by the Department of Agronomy of the Experiment Station are reported except those in which the comparative effects of legumes in cropping systems are being studied and those dealing specifically with tobacco production. Those experiments were reported in Bulletin 374 (1937), "Legumes in Cropping Systems", and Bulletin 379 (1938), "Soil Management and Fertilization for Tobacco."

The soil management experiments were located on land as nearly typical of important soil areas as could be determined when the experiments were begun. A number of these experiments have been discontinued. The first was at Burnside, Pulaski County, begun in 1908 and continued thru 1915 (Bulletin 199). The next was at London, Laurel County, in cooperation

with the Sue Bennett Memorial School, from 1911 to 1915 (Bulletin 199). One was in cooperation with the Lincoln Institute in Shelby County, from 1914 to 1922 (Bulletin 228). The Russellville (Logan County) Experiment Field was established in 1913 and continued thru 1924 (Bulletin 272). The Lone Oak (McCracken County) Experiment Field was established in 1913 and continued thru 1932 (Bulletins 272 and 322). The Hopkinsville (Christian County) Experiment Field was established in 1922 and continued thru 1929 (Bulletin 299). The "Renewed Fertilizer Experiments" and "Continuous Corn Culture Experiments" on the Experiment Station farm at Lexington were discontinued in 1931 and 1932, respectively (Bulletin 331).

EXPERIMENTS IN PROGRESS

As previously indicated, the objective in most of the soil management experiments herein reported is, first, to determine what mineral nutrients required by crops may be deficient and, after supplying these, to use legumes and grasses in the cropping system for nitrogen fixation and conservation, along with the use of manure on a practical basis. The ultimate object is to develop a system of soil management that provides an abundance of nutritious pasture and hay so that the grain requirements for livestock may be reduced to a minimum, and to increase the productivity of the soil to the economic limit so as to reduce to a minimum the acreage required to produce the grain needed for livestock and other purposes.

The grass type of farming is not only best for the type of livestock produced in Kentucky, but it is best for tobacco production, which is the largest single source of cash income for the farmers of Kentucky. The grass type of farming is the only type that will protect most of the land in Kentucky from serious erosion. It enables farmers of the Central Bluegrass region to keep 65 to 80 percent of the plowable land in grass. Such a system is possible in other parts of the state if the soil is treated with lime and sufficient phosphate, for it is chiefly the phosphate content of the Bluegrass soils that makes the grass type of farming possible.

Increasing the productivity of the soil need not mean a larger total production, if larger production is not desirable. It may and should mean more economical production thru

decreased labor and higher quality of both plant and animal products. The greatest contribution to both economical production and high quality is the soil improvement and conservation made possible thru increasing pasture and hay acreage and reducing the acreage devoted to tilled crops, such as corn and tobacco, that so greatly increase susceptibility to erosion and leaching.

THE LEXINGTON SOIL EXPERIMENT FIELD

This field was established to represent the highly phosphatic soils of the Central Bluegrass region. The soil of this field is Maury silt loam, a type found on the Trenton limestone formation, principally in Fayette, Jessamine, Boyle, Mercer, Woodford, Scott, and Bourbon Counties, with smaller areas in contiguous counties. However, none of these counties is entirely covered by soil of this type. It is characteristic of the area that the phosphorus content of the soil may differ widely within a short distance. Even on the Lexington Soil Experiment Field there is a wide range within its area of eight acres, as is shown by analyses of composite samples of soil from plots 3 and plots 13, given below. The figures represent pounds of the elements in 2,000,000 pounds of surface soil (weight of an acre to the depth of about 7 inches):

	Plots 3 lbs.	Plots 13 lbs.
Total nitrogen	4,520	4,400
Total phosphorus	12,400	7,640
Total potassium	27,000	29,000
Acidity, moderate, pH approximately 5.6		

The land used for these experiments was occupied by bluegrass sod for a number of years prior to 1900, when it was plowed and used for miscellaneous cropping until the experiments were started in 1911. So far as can be ascertained, no lime or manure was used on any part of the field prior to this experiment. Some fertilizer tests were made on a small part of it from 1900 to 1903, but were of such a nature that they did not affect the uniformity of the land for use in these experiments. The experiments on this field consist of fertilizer and liming tests and a comparison of crop rotations and continuous corn culture. A detailed report and discussion of the results thru 1931 will be found in Bulletin 331.

Thru this period a four-year rotation of corn, cover crop, soybeans, wheat and clover was used for the liming and fertilizer tests. For the larger part of this period the cornstalks were left on the ground, and the wheat straw and soybean straw were returned to the ground to be broken for corn. Since the rotation was changed, beginning in 1932, only a brief resume will be given of the results previous to the change.

Neither the fertilizer treatments nor the use of lime had any appreciable effect on the crops in this rotation. Superphosphate (16 percent) was used at an average rate of about 160 pounds per acre per year. Muriate of potash was used at an average annual rate of about 85 pounds per acre for the period, 1911–1931. Applications of fertilizers for the four years of the rotation were made on the corn ground. On a soil containing so much phosphorus, a phosphate fertilizer would not be expected to increase yields. There were in the test six comparisons of potash treatments with treatments similar except for potash. The average annual increases per acre for potash on the various crops were as follows: 20 corn crops, 1.0 bushel; 16 soybean seed crops, 0.8 bushel; 6 soybean hay crops, 239 pounds; 17 wheat crops, 0.1 bushel; 13 clover crops, 319 pounds.

As already stated, the effect of limestone was not significant in this rotation. An average total of 7.5 tons per acre of ground limestone was applied between 1911 and 1922 on plots variously fertilized and unfertilized. There was an average difference for the limed plots of 4 bushels of corn, 0.3 bushel of soybeans, 0.8 bushel of wheat, none of clover hay, and 116 pounds of soybean hay. It is doubtful if the difference in corn has any significance.

Crop residues did not increase appreciably the yield of any of the crops, the largest increase being about 375 pounds of clover hay as between plots 10 and 13. This was probably due to the potash returned in the residues.

The average yields of the crops on all the plots in the four-year rotation were, in round numbers, as follows: Corn, 54 bushels; soybeans, 19 bushels; soybean hay, 4,200 pounds; wheat, 27 bushels; clover hay, 3,960 pounds. The soybeans, as a regular crop, were threshed part of the time and cut for hay part of the time. There were four clover failures. Soybeans were used as a substitute and cut for hay in three of the four years. This soil

is fertile enough to produce a much higher yield of corn if the rainfall were sufficient. (See Bulletin 272, page 294.)

A three-year rotation of corn, wheat and clover was compared with the four-year rotation discussed above. The rotation was run on two sets of plots, one limed and one unlimed. The cornstalks and wheat straw were returned to the land. The yields of corn and clover in the two rotations were practically the same for the similarly treated plots. The yields of wheat in the three-year and the four-year rotations, for similar treatments, were 21.8 bushels and 27.4 bushels, respectively. The results on wheat raised the question as to whether the difference was due to the effect of the rotations on fertility or whether other factors, such as differences in seed bed, affected the yields. Rotation experiments were started in 1920 for studying this question. The results of these rotations were reported in Bulletin 374 (1937).

Corn was grown on this field in continuous culture, with and without a legume catch crop. The results of this test, also, are reported in Bulletin 374.

In the seeding of 1923, alfalfa was substituted for red clover in the rotations. A good early stand was obtained on all plots, but it died on all but the limed plots. Plots treated with limestone and potash showed a marked superiority over those treated with limestone only. After harvesting the wheat, the entire series of plots was broken and reseeded to a mixture of red clover and alfalfa. In 1924 the growth on the unlimed plots was nearly all clover, whereas on the limed plots it was nearly all alfalfa. The average yield on the plots receiving potash in addition to lime and phosphate treatment was 6,622 pounds per acre for two cuttings, while the yield on plots similarly treated except for potash was 5,400 pounds per acre.

The Changed Rotations. Beginning in 1932, changes were made in the rotations on this field. The corn, soybeans, wheat and clover rotation was changed to corn, wheat and two years of alfalfa. The plots used for the three-year rotation and continuous corn culture were used for a four-year rotation of barley followed by three years of alfalfa.

In both of these rotations the plots that had not been previously limed were limed at the rate of 2 tons of ground lime-

stone per acre, in 1932. The plots that had been previously limed were not relimed (see page 328 for rate).

In the new four-year rotation the same fertilizer treatments were used as in the old four-year rotation. Superphosphate was applied at the rate of 400 pounds per acre, and muriate of potash at the rate of 200 pounds, when wheat was sown. Corn was manured uniformly on all plots at 8 tons per acre.

In the barley rotation one set of plots (No. 17) had been limed sufficiently in the old rotation; the other set (No. 16) was limed and treated with potash at the same rates as in the corn rotation.

The reasons for the changes in the experiments were that crop residues had proved ineffective in increasing yields and that it was believed that soybeans are not a good crop to use regularly under Kentucky conditions. A rotation of corn, soybeans, wheat and clover requires breaking the ground twice in four years, the expense of seeding a winter cover crop, and two seedings for the two legumes in the rotation. The new rotations require but one breaking of the ground in four years. The special cover crop is eliminated and only one seeding of a legume crop is required, except when the regular seeding fails to give a stand.

Where manure is used on corn, and a legume, as soybeans, follows the corn, the fixation of nitrogen by the beans is probably reduced to the extent that the residue of nitrogen applied in the manure supplies nitrogen to the beans. If a non-legume, as wheat, follows the corn, the residue of nitrogen is further reduced and the legumes following the wheat will be supplied with less nitrogen from the soil and will fix more from the air.

Another reason for trying alfalfa in the rotation was that it may be cut three and four times a year, making possible more hay on a smaller acreage and a larger acreage in permanent pasture, which is a desirable practice in Kentucky to prevent erosion and reduce the tilled acreage necessary to maintain livestock.

The crop yields in these rotations are given in Table 1.

Discussion of Results. Phosphorus had no appreciable effect on the yield of crops. Six comparisons of its effect can be made in the series of tests. The largest effect apparently was to

increase the yield of second-year alfalfa hay by 68 pounds per acre per cutting.

Since phosphorus is not a limiting element in this soil, there are six comparisons in each of the four series of plots that may be made of the effect of potash. This gives twenty-four replications of the test in the four series. As an average of these tests,

Table 1. Average crop yields per acre in the corn-wheat-alfalfa rotation, Lexington Soil Experiment Field. (Alfalfa-Average per Cutting)

Plot No.	Treatment*	Corn 7 crops	Wheat 7 crops	1st-year alfalfa 14 cuttings 7 years	2nd-year alfalfa 13 cuttings 6 years
		bushels	bushels	pounds	pounds
1	MLP	62.7	23.2	2416	2924
2	MLK	63.4	24.4	2589	2883
3	ML	63.5	25.0	2330	2771
4	MLPK	65.3	27.9	2581	2674
5	MLPK	67.0	27.3	2593	2601
6	MLP	64.8	27.7	2308	2396
7	MLK	69.3	28.6	2549	2652
8	ML	67.2	26.9	2275	2464
9	MLPK	70.5	26.7	2627	2755
10	ML	69.5	26.1	2179	2558
11	MLP	66.7	27.7	2152	2719
12	MLK	70.1	27.7	2410	2998
13	ML	68.1	25.8	2140	2802
14	MLPK	69.7	26.0	2622	3056
15	MLPK	70.8	25.8	2924	3290

Barley-alfalfa rotation, same field

Plot No.	Treatment*	Barley 7 crops	1st-year alfalfa 14 cuttings 7 years	2nd-year alfalfa 13 cuttings 6 years	3rd-year alfalfa 11 cuttings 5 years
		bushels	pounds	pounds	pounds
16	MLPK	49.8	2547	2984	3052
17	MLP	49.5	2324	2885	2916

* M = 8 tons manure for corn and barley, L = limestone. Plots 1 to 5, plots 10 to 14, and plot 16 were limed at the rate of 2 tons per acre in 1931. The other plots were limed at an average total rate of 7.5 tons per acre between 1911 and 1922. P = superphosphate. K = muriate of potash. Plot 15 on each series was manured heavily in the rotation period, 1924–27, and is not used in determining the effects of lime and fertilizers. Plots 6 and 10 did not receive crop residues in the former rotation and are not used in comparisons to determine effects of fertilizers. In addition to the standard applications of fertilizers, the corn on plots 5 and 15 was fertilized in the hill with 200 pounds per acre of a 4-8-6 fertilizer. For the effect, compare plot 5 with plot 4 and plot 15 with plot 9.

corn was increased 2.5 bushels, wheat 0.7 bushel, first-year alfalfa hay 294 pounds per acre, and second-year alfalfa hay 151 pounds per acre. The alfalfa was cut on an average of three times a year, but yield was determined only on the cuttings that were fairly free from weeds. It was estimated, however, that there was as much alfalfa in the weedy cuttings as in the clean cuttings. If this be true, the effect of 200 pounds of muriate of potash was to increase the yield of hay 1,335 pounds per acre for the two years. There were times when the alfalfa might have been cut a fourth time.

In establishing the rotation there were two years of first-year alfalfa and two years of second-year alfalfa that were not affected by manure applied to the corn. The effect of potash was slightly greater on the first-year alfalfa before it was affected by manure than after, but this was not true for second-year alfalfa. The effect of potash in the barley rotation did not appear as great as in the corn rotation.

It is evident that any amount of manure that is economical for corn will not supply enough potash for alfalfa in a rotation like this. If enough manure were applied to meet the needs of the alfalfa for potash, it would, on land of the productivity of this, supply more nitrogen than is needed for corn and wheat and thus supply nitrogen to the alfalfa and slow up nitrogen fixation. The yield of alfalfa was about 7.5 tons per acre for the two years. This amount of alfalfa contains approximately 300 pounds of potash. A ton of manure contains about 10 to 12 pounds of potash. It is highly probable that some of the alfalfa failures so common in the older alfalfa regions is due to potash deficiency.

On soils deficient in phosphorus, heavy fertilization with phosphates is essential to good alfalfa production.

A comparison of the more recent 2-ton rate of liming with the older and heavier liming shows 35 pounds per acre per cutting in favor of the old liming rate on first-year alfalfa, and 280 pounds per acre per cutting in favor of the more recent lighter rate of liming on second-year alfalfa.

In the barley rotation, 8 tons of manure for barley was too heavy and caused the barley to lodge and damage the alfalfa.

A number of alfalfa seedings made on the wheat and barley have failed and summer seedings had to be made.

Possibly a mixture of alfalfa and timothy would be preferable to alfalfa alone.

It is the opinion of the writers that alfalfa should not be grown more than three or four years in succession on the same land. However, they are not prepared to say that the rotations used in these experiments are satisfactory—they are suggested for trial.

The yields of corn were considerably better in the last than in the first rotation, no doubt because manure was used in the latter, whereas crop residues were used in the first. The yields of wheat differed little. It is not possible to determine how much difference in weather conditions may have influenced the yields. The yields of hay were greater for two years of alfalfa than for one year each of soybeans and red clover.

MANURING EXPERIMENTS AT LEXINGTON

In 1920 a manuring experiment was begun in a rotation of corn, wheat and clover, to determine (1) the most economical amount of manure to use, and (2) the relative effects of manure applied to the different crops in the rotation. The soil is Maury silt loam, containing approximately 4,700 pounds of phosphorus and 24,000 pounds of potassium in 2,000,000 pounds of surface soil. The cropping of the land for a few years previous to its use for this experiment was as follows:

1908–10.	Timothy.
1911.	Corn. Land dressed with soybean straw.
1912.	Oats.
1913–15.	Alfalfa.
1916–17.	Corn, manured, 12 tons per acre in 1917.
1918.	Oats.
1919.	Wheat. Seeded to clover.

The land was limed in 1913, before sowing to alfalfa, except a strip of uniform width thru the field. A large part of Series 200 of the manuring experiment was on this strip, each plot containing the same amount of limed and unlimed land. Because of the poor growth of clover on the unlimed land, it was limed in 1927, except for a strip 20 feet wide, left for observation of the effects of lime.

Corn failed in 1930 on account of drouth. Wheat failed in 1924 and 1928 on account of winterkilling.

Soybeans were used for hay as a substitute for clover when it failed in 1924, 1926 and 1928. (See Bulletin 374, page 136, for the effect of soybeans on corn yield.) Clover was almost a failure in 1930 because of drouth, and the crop of 1931 was a failure because of drouth in 1930. Korean lespedeza was used as a substitute, but did not grow high enough to cut, altho the stand was thick. Clover failed in 1937 also. Alfalfa was mixed with clover for the crops of 1929, 1931, 1932, 1933 and 1935. Two cuttings were made in 1932 and 1935 and are included in the average yields. An attempt is being made in this rotation to develop a strain of clover that is adapted to a three-year rotation. The strains of clover now available seem not to be adapted to a three-year rotation because of the development of diseases to which they are not sufficiently resistant.

From the beginning of the experiment, thru 1931, manure was applied at the rates of 4, 6, 8 and 10 tons per acre on the clover sod, before breaking for corn. The same rates of application were made on another set of plots after the land was broken for corn. As an average of all rates, there was practically no difference in the effect on any of the crops of the two methods of application. Beginning in 1932, the manure was applied on the sod on both sets of plots, thus giving duplicate tests of each rate.

Thru the crop of 1933, manure was applied on wheat in late fall or early winter at the rates of 4, 6 and 8 tons per acre, and on another set of plots for clover at the same rates soon after the wheat was harvested. There was no significant difference in the wheat in the two methods of applying the manure, as an average of all rates of application. The manure applied on the young clover increased the yield of clover 200 to 300 pounds per acre over that applied on the wheat, as an average of all rates. Manure applied on wheat and on clover increased the yield of clover considerably, as compared with applying it on corn, but the increase in corn was reduced so much, as compared with manure applied on corn, that it seems preferable to apply the manure on corn. Since the dates mentioned above, for wheat and clover, manure was applied on both sets of plots in late winter or early spring just before wheat began spring growth.

(See Bulletin 331 for results thru 1931.) The results of this experiment are given in Table 2, for the period after the rotation was fully established (1923) thru 1938.

Table 2. Average crop yields per acre in manuring experiments at Lexington.

Plot No.	Manure		Corn, Bus.			Wheat, Bus.			Clover, Lbs.		
	Tons per acre	Place of application	15 crops	Increase*	Ave. increase duplicate treatments	13 crops	Increase	Ave. increase duplicate treatments	12 crops	Increase	Ave. increase duplicate treatments
1	None		52.1	----	----	24.9	----		3371	----	
2	4		63.6	12.0	13.1	27.2	2.8	2.8	3762	422	346
3	6	On clover sod	64.0	12.8	14.2	28.0	4.0	3.5	4015	705	611
4	8		65.1	14.4	15.6	27.8	4.3	4.3	3964	685	703
5	None	before breaking.	50.2	----	----	23.0	----	----	3248	----	
6	10		69.6	19.2	17.9	28.8	5.5	4.6	4151	869	832
7	4	See text for	64.6	14.1		26.4	2.8		3586	269	
8	6		66.2	15.6		26.7	2.9		3867	516	
9	None	exceptions.	50.8	----		24.1	----		3385	----	
10	8		67.0	16.7		28.3	4.2		4057	721	
11	10		66.4	16.6		27.8	3.6		4082	794	
12	4	On wheat in early	58.9	9.7	9.5	27.0	2.7	3.2	4022	782	792
13	None	winter to 1933;	48.7	----		24.3	----	----	3191	----	
14	6	early spring	58.4	8.7	9.1	27.9	3.8	4.0	4259	961	910
15	8	since.	58.9	8.1	8.8	28.1	4.2	4.5	4179	774	926
16	4	On young clover	61.0	9.2		27.3	3.7		4313	801	
17	None	after wheat	52.8	----		23.4	----		3619	----	
18	6	harvest to 1933;	62.5	9.5		27.6	4.2		4432	858	
19	8	early spring since.	62.8	9.5		28.2	4.8		4606	1077	
20	None		58.4	4.9		24.8	1.4		4151†	667	
21	None		53.7	----		23.4	----		3439		

* Crop increases calculated on assumption of uniform variation of soil between check plots before treatment. See page 322.

† Sweet clover, except that in 1932 and 1935 the hay crop was principally alfalfa.

Discussion of Results. Since three series of plots are used for this rotation, there are six replications of each rate of manure applied for corn, and six for each rate on wheat and young clover.

On land of the fertility of this, it does not seem profitable to use more than 5 or 6 tons of manure per acre for corn. The distribution of rainfall is not such as to enable the corn to fully utilize the nutrients supplied in the heavier applications; nor does it seem advisable to use the heavier applications on corn for

their effect on wheat and clover following. It may be that as the experiment grows older the effect of the larger rates will increase. It also seems advisable to use manure on corn rather than on wheat or clover, because of the lower yields of corn when the manure is applied on wheat or clover. The yield of clover is somewhat increased by applying the manure on the wheat or clover. The question arises as to why this is true, since clover should be able to obtain sufficient nitrogen thru fixation. It is probably the effect of potash in the manure rather than nitrogen. The lower yields of corn where manure is applied on wheat or clover may be caused by less fixation of nitrogen by the clover, thus providing less nitrogen for the corn. Or they may be due to potash deficiency.

Beginning in 1939, manure will be left off for a time, and one half of each plot will be treated with fertilizer potash to determine its effect on the crops of the rotation. Symptoms of potash deficiency have appeared in the corn on the check plots, as would be expected where no return of manure has been made for such a long period.

An experiment in continuous corn culture with manure used at different rates was begun in 1920 and continued thru 1931. This was reported in Bulletin 331 With 15 tons of manure per acre in alternate years, the yield of corn was not kept up to that of corn on the unmanured check plots in the manure rotation experiment reported in the preceding pages, altho the productivity of the land in continuous culture was higher at the beginning of the experiment.

Continuous culture was discontinued in 1933, and a two-year rotation was begun consisting of corn and wheat, with sweet clover (lespedeza included in 1938) sown on the wheat, to be turned under the next spring for corn. The series of plots was divided to make two large plots, each containing one half of all the former plots. The yields of corn and wheat were as follows:

	Corn	Wheat
1934	40.2	.....
1935	40.7	14.5
1936	24.8	14.2
1937	48.2	26.9
1938	81.5	24.7
Average	47.1	20.1

The average yields of corn and wheat on the unmanured check plots for the same period in the corn, wheat, clover rotation were 45 bushels and 23 bushels, respectively. Where 4 tons of manure was used on corn in the three-year rotation, the yields of corn and wheat were 58.2 bushels and 25 bushels, respectively.

For farmers who have a limited amount of land level enough for cultivation, a rotation of this kind has great possibilities. Manure should be returned or, if the legume should furnish enough nitrogen, potash should be used, and on soil deficient in phosphorus a phosphate should be liberally used. Beginning with 1939, potash will be applied liberally, as experiments have shown that this soil cannot long produce good yields without creating a potash deficiency. Where corn comes off in time, barley could be sown for a grain crop. If lespedeza alone is used as the legume, a winter grain should be seeded in the lespedeza. Italian rye grass could be used. Disking usually is sufficient for preparing a seed bed.

EXPERIMENTS AT THE WESTERN KENTUCKY SUBSTATION, PRINCETON

S. J. Lowry, Superintendent

Lowry Caldwell, Assistant Superintendent*

Experiments on Soil Derived from Limestone. An experiment was begun in 1926 on this soil for the purpose of testing rates of liming, the effectiveness of different degrees of fineness of limestone, different forms of liming materials, and the fertilizer requirements of the soil.

The soil has not been classified by the United States Bureau of Soils, but it is similar to Decatur silt loam. An analysis of the surface soil at the beginning of the experiment gave the following results, based on 2,000,000 pounds of soil:

Total nitrogen	2,680 lbs.
Total phosphorus	780 lbs.
Total potassium	32,600 lbs.
Acidity, strong, pH 5.2	

All the plots were planted to corn in 1926, without treatment, and produced an average yield of 54 bushels per acre. The season was very favorable for corn. So far as could be

* The field work on the soil management experiments was done under the supervision of Mr. Lowry and Mr. Caldwell.

learned, no lime had ever been used on the land, and little or no fertilizer.

The rotation used was corn, wheat, and a mixture of red clover, alsike clover, alfalfa and lespedeza. Alsike clover was left out after the 1934 crop.

Limestone and other liming materials were used in amounts to equal the indicated weights of pure limestone. The degrees of fineness used were 10-20 mesh, 40-50 mesh, 70-80 mesh, and 100 mesh and finer (100-X). The meshes indicated are the number per linear inch in the screen. The actual opening is less by the thickness of the wire of the screen. Prior to 1936, separates coarser than 100 mesh were washed to remove all adhering finer material possible. The 1- and 2-ton applications were of material all of which passed a 10-mesh sieve, and included the finer particles.

The 2-ton application of limestone was made when the experiment was started in 1927, and will not be repeated until the end of the sixth rotation period. The 1-ton application was made at the beginning and repeated after the third rotation period. One corn crop, three wheat crops and two hay crops have been affected by the second 1-ton application. The ⅓-ton applications were made when wheat was sown in each rotation period. Thus, at the end of the third rotation period (nine years) 1 ton of these fractional applications had been applied, and at the end of the sixth rotation period 2 tons will have been applied. At the end of eighteen years there will be a comparison of 2 tons applied at the beginning, 2 tons applied in two applications of 1 ton each, and 2 tons applied in six applications of ⅓ ton each. The 500-pound application on plot 29 was repeated at the beginning of the fourth rotation period. The other small applications were made at the same time as the ⅓-ton applications.

Superphosphate was used at the rate of 240 pounds (20 percent equivalent) per acre for corn and for wheat, thru 1935, after which it was used only on wheat. Beginning with 1937, the rate was changed to 250 pounds. Triple superphosphate (plot 11) was used at an equivalent rate. On plot 12 one half the standard application of superphosphate was used.

Raw ground rock phosphate (100 mesh, of approximately 32

percent grade) was used at the rate of 600 pounds per acre for three applications at the same time superphosphate was applied. After that, 300 pounds of 300-mesh material was used at the same time superphosphate was used, and was discontinued on corn at the same time superphosphate was discontinued.

Muriate of potash was used at the rate of 75 pounds per acre for corn and wheat thru 1935, except that in 1927-28 the rate was 50 pounds. Beginning with 1937 it was omitted from corn as was superphosphate.

Beginning with 1937, manure was applied to all plots for corn, at the rate of 6 tons per acre.

On plot 9, nitrate of soda was used at the rate of 100 pounds per acre at the hill, for corn, and 100 pounds per acre as a spring top-dressing for wheat.

All lime and fertilizer materials were applied broadcast and disked in unless otherwise indicated.

The crop yields for this experiment are given in Table 3. Corn was almost a failure in 1930 on account of drouth and is not included in the average. Some years the hay was largely lespedeza. Second cuttings were sometimes made and are included in the average yields.

The plots were cropped to corn without treatment in 1926 for a study of the variability in the productivity of the plots. The plot treatments were then "staggered" to reduce as much as possible error from soil variation. The corn yields (average of the three series of plots) in the preliminary cropping (1926) are given in the last column of Table 3. The season of 1926 was unusually favorable for corn. Several seasons since the experiment was begun have been very unfavorable for corn; hence the average yield for the entire period for the check plots is lower than in the preliminary cropping. In 1938 the yields of corn on some plots were more than 70 bushels per acre.

Discussion of Results. The outstanding results of this experiment are:

1. The pronounced effect of lime and of phosphate fertilizers in increasing yields.

2. The effectiveness of small applications of liming mate-

Table 3. Average crop yields per acre in liming and fertilizer tests, Western Kentucky Substation (limestone area).

Plot No.	Treatments[1]	Corn 11 crops		Wheat 12 crops		Hay 11 crops		Yield of corn, preliminary cropping
		Yield Bus.	Increase[3]	Yield Bus.	Increase	Yield Lbs.	Increase	
1	O	44.6	.....	11.6	.....	1936	.....	59.1
2	L	49.9	5.3	12.6	1.0	2967	1099	60.8
3	P	51.6	7.1	15.3	3.7	2835	1034	62.0
4	O	44.5	.....	11.6	.....	1733	.....	59.5
5	PK	47.8	4.6	14.1	3.3	2504	841	56.7
6	LP	53.6	11.8	16.4	6.3	3753	2159	55.8
7	O	40.5	.....	9.3	.....	1524	.....	55.5
8	LPK	55.8	15.2	17.3	8.1	3613	2129	57.1
9	LPKN	58.3	17.6	23.1	14.0	3869	2424	57.6
10	O	40.8	.....	9.0	.....	1405	.....	53.1
10a	O	40.9	.....	9.2	.....	1618	.....	51.1
11	L Triple PK	55.9	14.1	16.7	7.4	4149	2527	49.8
12	L(½P)K	54.9	12.2	15.9	6.4	3536	1909	56.4
13	O	43.6	.....	9.6	.....	1631	.....	57.4
14	2LPK	56.8	15.4	17.4	8.3	4278	2734	51.8
15	⅓L(10–20)PK	52.0	12.7	14.6	5.9	4022	2564	46.8
16	O	37.1	.....	8.2	.....	1371	.....	48.3
17	⅓L(40–50)PK	52.8	15.5	15.2	7.0	4244	2875	48.9
18	⅓L(70–80)PK	51.7	14.2	14.4	6.3	4025	2659	48.0
19	O	37.7	.....	8.1	.....	1364	.....	50.0
20	⅓L(100–X)PK	52.8	12.2	15.5	6.8	3853	2357	52.6
21	⅓L(100–X)PK[2]	55.5	11.9	16.3	7.1	3951	2323	56.2
22	O	46.5	.....	9.8	.....	1760	.....	57.2
22a	O	40.8	.....	9.1	.....	1676	.....	53.6
23	⅓L(Hydr.)PK[2]	54.0	13.8	17.0	7.9	4136	2528	56.0
24	250 Lbs. (Hydr.) LPK	52.1	12.5	15.8	6.8	3658	2118	57.6
25	O	39.0	.....	9.0	.....	1472	.....	53.7
26	250 Lbs. L(100-X)PK	47.7	9.1	13.8	4.9	3529	2065	49.4
27	⅓L(marl)PK	50.8	12.5	15.1	6.4	3874	2419	53.3
28	O	37.9	.....	8.6	.....	1447	.....	50.7
29	¼L(100–X)RpK	47.2	8.6	12.5	3.8	3115	1613	50.0
30	LRpK	50.6	11.4	13.7	4.8	3659	2101	51.3
31	O	39.9	.....	9.0	.....	1613	.....	50.9

[1] L = limestone unless otherwise specified. One ton application unless otherwise indicated by figure preceding L; 10–20, etc. refers to fineness. P = superphosphate, Rp = rock phosphate, K = muriate of potash, N = nitrate of soda.

[2] The lime material and phosphate were mixed before applying thru 1935; applied broadcast 1927–30; drilled with wheat 1931–35. Not mixed afterward, but applied broadcast as on plot 20. There was no significant difference between the two methods. Beginning in 1936, limestone of 10 mesh and finer was substituted for the 100-X mesh limestone on plot 21.

[3] Increases calculated on the assumption of uniform variation of soil between check plots before treatment. See page 322.

rials made once per rotation as compared with heavier applications at the beginning of the experiment.

3. The effectiveness of the coarser fractions of limestone as compared with the finer.

Following are the average annual increases for the different rates of liming, including the phosphate and potash treatment, which was the same for all plots, thus leaving limestone as the variable.

Increase in yield, per acre, due to liming.

	Corn bushels	Wheat bushels	Clover hay pounds
1 ton applied in 1926, repeated in 1936–38	15.2	8.1	2129
2 tons applied in 1926	15.4	8.3	2734
Average of all ⅓-ton applications made once in each rotation period	13.6	6.5	2613

In 1931 the plot with the 2-ton application of limestone yielded 3,100 pounds of alfalfa hay per acre for the first cutting, when alfalfa and clover failed on the other plots. Deducting this yield, the yield of hay was no greater with the 2-ton application than with ⅓ ton of 10-20 mesh limestone. In 1933 clover failed with all the 1- and 2-ton rates of liming, but made fair yields with all the smaller applications made when the preceding wheat crop was seeded.

It is to be noted that the 10-20 mesh limestone (plot 15) was more effective than the 100 mesh and finer (plots 20 and 21). The most effective separate was 40-50 mesh.

The total of each of the ⅓-ton applications per rotation was 1⅓ tons in twelve years. The second application of 1 ton is to last thru the second nine-year period of the experiment. As already stated, the 2-ton application made in the beginning is to last for eighteen years.

It is not surprising that the finest fraction of limestone is no more effective than the coarsest. These applications were made when wheat was sown and were subject to leaching of the heavy rainfall thru the winter before the legumes were sown; then again to another winter's leaching preceding the year of harvest. The finer the limestone, the more the surface exposure, and presumably the more readily it goes into solution and leaches. In tests made in the greenhouse, the lime is not subject to leaching unless enough water is added to produce percolation thru the pots. It is believed that limestone ground to pass a 10-mesh sieve is satisfactory for small applications.

Burned lime, marl and ground limestone were about equally effective in increasing crop yields when used in amounts to con-

tain the same calcium carbonate equivalent. The comparison was on a basis of ⅓ ton of limestone per acre for each rotation period.

The use of small applications of lime enables farmers of limited means to lime much larger areas and get better legumes for a given expenditure. The returns from the lighter rate of liming will help to finance future liming. Applications of small amounts of limestone may be mixed with fertilizer and drilled in with it, thus saving the expense of separate application. Some grain drills have a capacity of 1,000 pounds of fertilizer per acre. One thousand pounds of a 2:1 mixture of limestone and superphosphate would contain ⅓ ton of limestone and 333 pounds of superphosphate. Except for alfalfa, it is better to lime a larger area lightly than a smaller area more heavily. Attention is called to the fact that this soil is rather strongly acid.

This experiment does not represent the full possibilities of increasing crop yields, for no manure was returned until 1937. Only two corn crops and one wheat crop have been affected by the manure. The reason for not using manure from the beginning was that the effects of the lime treatments might be obscured by the effect of manure. An examination of the yields on the experiment fields reported in the following pages shows the beneficial effects of the continued use of manure.

A comparison of plots 8 and 30 shows that on this soil superphosphate is more effective than rock phosphate at the rates at which they were used. However, the effect on hay was practically the same. The relative amounts of phosphorus applied in the two forms were approximately one part in superphosphate to three parts in rock phosphate. As between plot 12 and plot 30, the ratio was approximately one to six. However, the accumulation of the larger reserve of phosphorus from rock phosphate may change the relative effects in the future.

As too much lime sometimes depresses the effect of rock phosphate, the small application of lime on plot 29 was made to test this effect. The 1-ton application was decidedly more effective. An application of 3 or 4 or more tons of limestone has had a depressing effect on rock phosphate on some soils in the state, while on others it has not, as will be seen in experiments reported in the following pages.

There are only two comparisons in which the effect of potash

can be determined—they are plots 3 and 5 and plots 6 and 8. The effect is not conclusive of its need up to the present. However, if manure is not returned, a deficiency of potash will sooner or later appear on most soils.

Experiments on Soil of Sandstone Origin. The soil on which this experiment is located is of sandstone origin. The soil has not been classified by the United States Bureau of Soils, but it is believed to be Tilsit silt loam, the prevailing type in the uplands of the Western Coal Field and the surrounding sandstone area. An analysis of the soil at the time this experiment was begun gave the following results, based on 2,000,000 pounds of surface soil:

Total nitrogen	1,980 lbs.
Total phosphorus	900 lbs.
Total potassium	30,000 lbs.
Acidity, moderate, pH 5.5	

The soil was in a badly depleted state when the land was purchased for the Substation. The plots for this experiment were laid out in 1928 and given a preliminary cropping to corn as a basis for distributing the plot treatments to reduce error from soil variation as much as possible. The average yield of all the plots was 12 bushels per acre. That the season was fairly favorable for corn was shown by land on the limestone area which had fair management yielding more than 50 bushels to the acre.

The rotation used in this experiment (begun in 1929) was corn, wheat, and hay from a mixture of red clover, alsike clover, lespedeza, timothy and redtop seeded at the rate of about 20 pounds per acre.

Limestone was applied at the rate of 2 tons per acre when the experiment was started.

Superphosphate (20 percent equivalent) was used at the rate of 480 pounds per acre for each rotation until 1936 when the rate was changed to 500 pounds.

Muriate of potash was used at the rate of 150 pounds per acre for each rotation.

These fertilizers were applied broadcast when wheat was sown, except on plots 14–18, where it was applied broadcast when corn was planted. An exception to this will be discussed under "Hill application of fertilizers for corn."

Nitrate of soda was applied at the rate of 50 pounds per

acre, at the hill, for corn (40 pounds the first two years), and 100 pounds per acre as a top-dressing for wheat in the spring, regardless of when the phosphate and potash were applied.

Beginning in 1933, manure was used for corn at a uniform rate of 5 tons per acre on all plots, for one round of the rotation, after which it was applied to each plot at a rate equal to the weight of the crop of the rotation removed from the corresponding plot the previous year, wheat grain excepted.

Table 4. Average crop yields per acre in liming and fertilizer tests, Western Kentucky Substation (sandstone area).

Plot No.	Treatments*	Corn Ave. 9 crops		Wheat Ave. 9 crops		Hay Ave. 8 crops		Yield of corn, preliminary cropping
		Yield Bus.	Increase†	Yield Bus.	Increase	Yield Lbs.	Increase	
1	M	20.3	.....	2.7	.....	899	.....	12.7
2	MLP	39.4	17.5	14.2	11.0	3783	2741	12.8
3	MLPK	39.4	15.9	14.7	10.9	3853	2670	13.4
4	M	25.1	.....	4.3	.....	1328	.....	11.6
5	MLPN	41.2	16.3	19.2	15.3	4030	2727	10.8
6	MLPKN	41.8	17.1	18.9	15.3	3883	2605	10.7
7	M	24.5	.....	3.2	.....	1253	.....	10.8
8	MP	35.7	10.7	11.2	7.5	2553	1248	10.6
9	MPK	34.6	9.2	11.0	6.9	2575	1217	11.3
10	M	25.9	.....	4.6	.....	1410	.....	13.2
10a	M	23.6	.....	4.0	.....	1258	.....	12.3
11	MPN	37.0	12.5	17.7	13.4	2845	1436	11.8
12	MPKN	37.4	12.0	17.6	12.9	3233	1673	11.6
13	M	26.3	.....	5.0	.....	1711	.....	13.7
14	MLP**	42.1	15.5	11.8	6.9	3983	2336	12.3
15	MLPK**	44.0	17.0	12.6	7.8	4040	2456	11.1
16	M	27.3	.....	4.7	.....	1520	.....	11.8
17	MLPN**	45.4	19.1	17.7	13.1	3870	2400	14.2
18	MLPKN**	46.3	21.0	17.6	13.2	3970	2550	14.9
19	M	24.3	.....	4.3	.....	1370	.....	14.3
20	MLP	40.5	17.9	15.5	11.6	4438	3198	12.2
21	MLPK	40.2	19.4	14.9	11.4	4340	3230	12.6
22	M	19.1	.....	3.1	.....	980	.....	11.4
23	MLPN	37.4	18.9	19.3	16.5	3875	2869	9.6
24	MLPKN	36.9	18.9	18.2	15.6	3578	2545	9.8
25	M	17.4	.....	2.3	.....	1059	.....	7.3

* M = manure, L = limestone, P = superphosphate, K = muriate of potash, N = nitrate of soda.

** Fertilizers applied on corn land.

† Increases calculated on the assumption of uniform variation of soil between check plots before treatment. See page 322.

Following the preliminary cropping of 1928, all three series of plots were seeded to rye, without treatment. In 1929 the first series of plots was planted to corn, with the application of limestone and fertilizers as indicated in Table 4. The second series was limed and fertilized according to plan and planted to cowpeas, which were turned under, followed by a cover crop of rye

to be turned under for corn. The third series was also seeded to cowpeas, with similar treatment, followed by a rye cover crop and seeded to the grass and legume mixture. The crop yields in this experiment are given in Table 4. Corn and hay failed in 1930 on account of drouth.

Discussion of Results. The outstanding results on this experiment are the effects of limestone and superphosphate in increasing yields, which are very evident from an inspection of Table 4. Each limed treatment occurs three times in each series, giving nine plot replications in the three series. A summary of all these treatments shows practically no effect of potash on any of the crops. Nitrate of soda (50 pounds) at the hill, for corn, produced an average increase of 1.3 bushels per acre. One hundred pounds per acre as a top-dressing for wheat increased the yield an average of 5 bushels per acre.

One set of plots (plots 8, 9, 11, 12) in each series was not limed but had the same fertilizer treatments as those that were limed. It will be noted that there were three sets of plots that were limed and similarly fertilized. The following summary shows the increase of crops from the application of fertilizers, without and with ground limestone:

Treatment	Corn bushels	Wheat bushels	Hay pounds
LP	17.0	9.8	2758
P	10.7	7.5	1248
Increase due to limestone	6.3	2.3	1510
LPK	17.4	10.0	2785
PK	9.2	6.9	1217
Increase due to limestone	8.2	3.1	1568
LPN	18.1	15.0	2665
PN	12.5	13.4	1436
Increase due to limestone	5.6	1.6	1229
LPKN	19.0	14.7	2567
PKN	12.0	12.9	1673
Increase due to limestone	7.0	1.8	894
Average increase due to limestone	6.8	2.2	1300

Another interesting result of these tests is the relative effect of phosphate and potash used all on wheat, for the rotation, as

compared with all on corn, for the rotation. The following is a summary of the increases for treatments. The land in this comparison was all limed.

		P	PK	PN	PKN
Corn, bus., increases	P and K on wheat	17.7	17.7	17.6	18.0
	P and K on corn	15.5	17.0	19.1	21.0
Wheat, bus., increases	P and K on wheat	11.3	11.2	15.9	15.5
	P and K on corn	6.9	7.8	13.1	13.2
Hay, lbs., increases	P and K on wheat	2970	2950	2798	2575
	P and K on corn	2336	2456	2400	2550

It should be noted that nitrogen was applied direct for corn where the phosphate and potash were applied on wheat. There seems little doubt that it is better to use whatever phosphate and potash are needed, in a rotation like this, on the wheat. The explanations of the better effects probably are: first, wheat has a much shorter time in which to obtain its nutrients than has corn; second, the legume crop will have a larger reserve of phosphorus and potassium fertilizers if they are applied to wheat, and so makes better growth and fixes more nitrogen; and third, the manure returned to the corn makes up for the deficiency for corn following the application on the wheat crop.

The most important thing in increasing soil productivity is to produce good legume crops for nitrogen fixation and then conserve this nitrogen by returning the residues and manure from the crops to the soil. The straw and stalks are best utilized as bedding to conserve liquid manure.

Hill Fertilization Tests on Corn. From the beginning of the experiment each fertilized plot was divided into two parts. On one half all the fertilizers were applied as in the experiments the results of which have just been given. On the other half, 80 pounds of the superphosphate and 15 pounds of the muriate of potash were reserved from the standard broadcast applications and placed at the hill for corn, together with the 50 pounds of nitrate of soda where this material was used. This would make practically the equivalent of a 200-pound application of 4–8–4 fertilizer where all three ingredients were used or the same amount of an 0–8–0, 0–8–4 or 4–8–0 fertilizer, according to whether one or two of the materials were used. (The first figure of the analysis is nitrogen, the second phosphoric acid, and the third potash.)

From 1929 to 1934 the fertilizer was mixed with the soil in the hill, in a strip 3 to 4 inches wide and 10 to 12 inches long. From 1935 to 1938 the fertilizer was placed in parallel bands 3 to 4 inches to each side of the hill and slightly below the seed, at planting time. When nitrate of soda was used for corn on plots where all the phosphate and potash were applied broadcast, it was applied at the hill.

After two rounds of the rotation, the halves of the plots used for hill fertilization and those used for all broadcast application were exchanged. As there are sixteen fertilized plots in each series, and three series of plots, there were in the results a total of ninety-six plot replications, when all fertilizer combinations are included.

As an average of all these tests for the nine crops of corn, there was only 0.5 of a bushel in favor of hill fertilization. It was thought that the side band placements would be better than mixing with the soil, but the hill application by this method for four crops gave average results identical with the all-broadcast applications. This is in harmony with results obtained on the Campbellsville Experiment Field (see page 369). When small applications of fertilizer are to be used for corn or tobacco on land that has not been regularly fertilized, as is done in fertilizing sufficiently for small grain and grass and legumes in the rotation, there is little doubt that it is better to apply the fertilizer at the hill. However, as was previously stated, the important thing is to fertilize for the economic maximum growth of grass and legumes. When this is done and manure is conserved and used, sufficient nutrients for economic corn production will be supplied. If a nitrogen fertilizer is used for corn, it should be applied at the hill, but in a system of soil management like that followed in this experiment, it is not likely that its use will be profitable.

Comparison of Phosphates. In 1930 a test of the effectiveness of various forms of phosphate was begun on soil similar to that on which the preceding experiments were conducted. It was slightly lower in nitrogen and phosphorous, but of the same potassium content and same acidity. However, preliminary cropping to corn, without treatment, in 1929, showed it to be very unproductive, the average yield of corn being 3 bushels

per acre, whereas the average yield on the untreated check plots in the preceding experiments was 30 bushels for the same year. Since the grain yields were so low, the combined weight of grain and stover is given in Table 5. Because this area was extremely unproductive, it was thought it would provide a severe test of the phosphates, particularly of their availability to legumes.

The rotation used was corn, wheat, and a mixture of red clover, lespedeza, timothy and redtop. The phosphates tested were ordinary superphosphate, basic slag, raw phosphate rock ground to pass a 100-mesh sieve, and raw phosphate rock ground to pass a 300-mesh sieve. The basic rate of application from 1930 to 1935 was 600 pounds of 16-percent superphosphate (or the equivalent of 20 percent) per acre on the corn land, to last for the three-year rotation. Basic slag was used at a rate to supply the same amount of phosphorus as in the superphosphate application. The raw rock phosphate was used at the same weight per acre as the superphosphate, thus supplying approximately twice as much phosphorus as in the superphosphate. Beginning with 1936, the phosphate rates were reduced one half.

Muriate of potash was used at the rate of 300 pounds per acre for the rotation thru 1935, after which the rate was 150 pounds. Nitrate of soda was used thruout at the rate of 100 pounds per acre, at the hill, for corn, and at the rate of 100 pounds per acre as a top-dressing for wheat.

The phosphates and the potash were applied broadcast on the corn ground except on plots 11 and 12, where 100 pounds of superphosphate, 100 pounds of fine rock phosphate and 15 pounds of muriate of potash were reserved for application in the hill.

In 1930, 1,000 pounds of 100-mesh limestone per acre was used on the limed plots. From 1936 to 1938, 1,000 pounds of 10-mesh limestone per acre was applied when wheat was sown. Limestone was used in small quantities because on some soils heavy applications have interfered with the effectiveness of rock phosphate. Beginning with the second rotation period (1933), manure was returned to all plots for corn at the uniform rate of 6 tons per acre. The yields for this experiment are given in Table 5. Corn was a failure in 1930 on account of drouth.

Discussion of Results. Since a uniform treatment of

Table 5. Average crop yields per acre in a comparison of phosphates, Western Kentucky Substation.

Plot No.	Treatment*	Corn Ave. 8 crops		Wheat Ave. 8 crops		Hay Ave. 8 crops		Grain and stover preliminary cropping, lbs.
		Yield Bus.	Increase**	Yield Bus.	Increase	Yield Lbs.	Increase	
1	M	15.8	.....	2.9	.....	1278	.....	1253
2	MPKN	32.3	14.4	12.2	9.1	2503	1146	1293
3	MfRpKN	35.5	15.5	14.5	11.1	3145	1709	1313
4	M	22.1	.....	3.6	.....	1515	.....	1230
5	MBsKN	38.2	15.4	11.9	8.1	3365	1790	1347
6	MLPKN	40.0	16.4	14.0	9.9	3793	2158	1393
7	M	24.3	.....	4.3	.....	1695	.....	1280
8	MLfRpKN	38.2	14.8	12.2	8.2	4165	2548	1140
9	MLRpKN	36.1	13.5	11.0	7.4	3540	2002	1053
10	M	21.7	.....	3.3	.....	1460	.....	1213
11	MLPKN	33.6	14.0	12.1	9.2	2830	1505	1087
12	MLfRpKN	30.6	13.0	9.8	7.4	2620	1430	967
13	M	15.5	.....	2.0	.....	1055	.....	950

* M = manure, P = superphosphate, Bs = basic slag, fRp = 300-mesh rock phosphate, Rp = rock phosphate 100-mesh and finer, L = limestone, K = muriate of potash, N = nitrate of soda.

** Increases calculated on the assumption of a uniform variation of soil between check plots before treatment (see page 322).

potash and nitrogen was given all fertilized plots, the variables are the different phosphates, on limed and unlimed soil. The effect of limestone was significant only on the hay crop. The average annual increase of hay for limestone was 482 pounds per acre on the superphosphate and 300-mesh rock phosphate plots.

Using an average of all comparisons of superphosphate and 300-mesh rock phosphate, there was an increase of 0.5 bushel per acre each of corn and wheat in favor of superphosphate, while there was a difference in favor of rock phosphate of 293 pounds of hay per acre.

There was one comparison of rock phosphate 100 mesh and finer with 300 mesh and finer. If a comparison of plot 9 is made with an average of plots 8 and 12, there is practically no difference. If plots 8 and 9 are compared, there is a substantial difference in hay in favor of 300 mesh rock phosphate.

Basic slag was about as effective on corn and wheat as superphosphate, and more effective on hay.

The irregularity of the soil, as indicated by the check plots, makes it impossible to make accurate comparisons, but the tendency of the rock phosphate to be more effective on the hay crop seems significant. A more extensive test on more uniform

land is needed and is contemplated. (See page 340 for comparisons of superphosphate and rock phosphate on soil of limestone origin, on this farm.)

Other Experiments. There is an experiment on this farm on soil management and fertilization for tobacco, the results of which were published in Bulletin 379 (1938). There is also an experiment in which different legumes are compared in rotations with corn and wheat, the results of which were published in Bulletin 374 (1937).

THE BEREA SOIL EXPERIMENT FIELD

H. H. Harrison, Berea College, in Charge

The Berea Soil Experiment Field is conducted in cooperation with Berea College, on land belonging to Berea College, in Madison County, about two miles east of Berea, on a soil type designated by the United States Bureau of Soils as DeKalb silt loam. Similar soils are found at the base of the chain of knobs surrounding the Bluegrass region. These soils are of a light color, generally quite acid, low in phosphorus and nitrogen, and poorly drained where the land is level or nearly so. An analysis of a sample of surface soil from this field gave the following results, stated as pounds in 2,000,000 pounds of soil (the weight of an acre to the depth of about 7 inches):

Total nitrogen	2,200 lbs.
Total phosphorus	880 lbs.
Total potassium	19,000 lbs.

The surface soil is strongly acid (pH 4.5), while the subsoil is more so.

Work was begun on this field in 1913. A rotation of corn (rye cover crop), soybeans, wheat and clover was tried at first, but the soil was so poorly drained that wheat and clover either failed or made very poor growth.

In the spring of 1917 the field was tile-drained, and the four-year rotation of corn, soybeans, wheat and clover was tried again, but wheat made such poor yields that, after four years, rye was substituted. Clover and grass were sown on the rye, and the rye cut before maturity, since pasturing could not be practiced on experimental plots as is done in farm practice. The clippings were removed if too heavy, but frequently were left on the ground.

Beginning with 1932, the rotation was changed to corn, rye, and two years of legume and grass mixture. The rye was used as in the first rotation.

Limestone was used twice, at the rate of 2 tons per acre, between 1913 and 1921. It was applied on the broken corn ground. In addition to this, in 1913, fractional applications were made in the other series as follows: Series 200 had a one-fourth application; series 300, a half application; and series 400, a three-fourths application. No more limestone was used until 1928. Between 1928 and 1930 the limed plots in each series received another application at the rate of 1 ton per acre. This makes an average of 5.75 tons per acre in twenty-six years.

Superphosphate of 16 percent grade, or its equivalent, was used at the rate of 800 pounds per acre on the corn ground, for the rotation, for two rounds, with fractional applications in the beginning as with limestone. Rock phosphate (approximately 32 percent grade) was used in the same way, but at twice the rate of superphosphate. After two rounds of the rotation, the rates were reduced one half. These applications were approximately equal to an average annual application of 100 pounds of 20 percent superphosphate and 260 pounds of rock phosphate per acre. The rock phosphate applications contained approximately four times as much phosphorus as the superphosphate.

Muriate of potash, or its potash equivalent, was used at the rate of 400 pounds per acre on the corn ground for three years, with fractional applications the first year as in the case of the other materials. After this it was used at the rate of 200 pounds per acre for the rotation till 1930, after which it was used at the rate of 100 pounds per acre. The applications were equal to an average annual application of 50 pounds of muriate of potash per acre.

The fertilizers were applied broadcast on the ground broken for corn and disked in, except that rock phosphate was applied before breaking about half the time.

Manure was used on the corn ground at the rate of 6 tons per acre on all plots except No. 1, from 1917 to 1921. Since then it has been applied on each manured plot on the corn ground at a rate equal to the weight of the three crops removed from the corresponding plots the previous year, except in 1927-28, when

the amount returned to each plot was equal to the weight of the crops removed from the check plots the preceding year. Four cowpea crops have been turned under preceding the corn crop, when the clover crop failed or was poor.

The crop yields for the various fertilizer treatments are given in Table 6. The corn crop of 1930 is not included on account of the low yields due to drouth. The soybean crop of 1913 is missing from the averages because workmen misunderstood instructions to harvest by plots. The crop of 1930 was so poor that it reduced the average of the seventeen-year period by about 150 pounds. The first clover crop was not obtained until 1918, because of conditions previously mentioned. The clover crop for harvest in 1923 did not survive the winter.

Beginning in 1926 (year of harvest), timothy and common lespedeza were sown with the clover—a mixture of red and alsike—and in 1928 redtop and Korean lespedeza were added. In 1927, 1928 and 1929 small amounts of alfalfa and sweet clover were included on one half of each plot, for observation, and in 1930 they were included on the whole of the plots. Alfalfa and sweet clover made a fair growth on the plots treated with limestone and phosphates and were somewhat better where potash was included. Common lespedeza and alsike clover were omitted, beginning with 1931. Since that time the mixture has been red clover, alfalfa, lespedeza and timothy, except that in 1932 red clover was used alone.

In most years lespedeza reseeded itself the first year and made a fair stand on those plots (unlimed) which did not produce a good growth of other clovers and grasses. On the limed plots the lespedeza was largely choked out by the other species of the mixture.

The corn crops and legume-grass hay crops are divided into three periods so that the last period for each crop coincides with the period following the change in rotation. The hay yields include all second cuttings.

Discussion of Results. There are not enough check plots in this experiment to give a close measure of soil variation; hence small differences in effects of treatments are not significant. However, certain treatments produce such pronounced effects that there can be no doubt as to their significance.

Table 6. Average crop yields per acre, Berea Soil Experiment Field.

Plot No.	Treatment*	Corn, bus., 25 crops					Soybean hay, lbs., 18 crops			
		First 10 crops	Next 10 crops	Last 5 crops	25 crops	Increase	First 9 crops	Second 9 crops	18 crops	Increase
1	O	16.7	10.3	12.5	13.3	—12.5	1747	1879	1813	—983
2	ML	39.2	.....	.....	.....	.....	3438	.....	2280	.....
3	M	30.2	25.4	18.0	25.8	.....	2637	2954	2796	..
4	MP	36.5	44.2	33.4	39.0	13.2	3187	4019	3603	807
5	MRp	33.6	49.4	35.4	40.3	14.5	3115	3781	3448	652
6	MLP	41.7	50.1	42.9	45.3	19.0	4118	4513	4316	1271
7	MLRp	41.4	49.7	44.6	45.4	19.1	4006	4649	4327	1282
8	M	26.3	27.6	23.7	26.3	.....	2651	3439	3045	.
9	MLPK	43.8	54.7	44.0	48.2	21.9	4457	4959	4708	1663
10	MLRpK	39.2	51.9	47.5	45.9	19.6	3622	4579	4100	1055

Plot No.	Treatment*	First-year legume-grass hay, lbs., 20 crops					Second-year legume-grass hay, lbs., 6 crops	
		First 7 crops	Next 7 crops	Last 6 crops	20 crops	Increase	Yield	Increase
1	O	76	359	618	338	—243	993	—306
2	ML	649	1429	.....	.....	.....	.....	.....
3	M	416	716	615	581	.....	1299	...
4	MP	670	1733	1787	1377	796	3002	1703
5	MRp	760	1653	2773	1677	1096	3285	1986
6	MLP	2029	3497	3411	2957	2215	3736	1586
7	MLRp	1754	3449	3581	2895	2153	4205	2055
8	M	426	864	968	742	.....	2150	.....
9	MLPK	2016	4039	4091	3346	2604	4429	2279
10	MLRpK	1556	3917	4024	3123	2381	4435	2285

* O = no treatment, M = manure, L = limestone, P = superphosphate, Rp = rock phosphate, K = muriate of potash. Plots 3 and 8 were used as check plots to determine the effect of limestone and fertilizers. The increase for treated plots was determined by comparison with the nearest check plot. The minus (—) figure in the increase column for plot 1 is the difference between plot 1 and plot 3. Plot 2 was used for a comparison of superphosphate and 300-mesh rock phosphate, beginning in 1931. (See page 354.)

The outstanding results are the increases in yield produced by limestone and phosphate. Up to the time the limestone plot (plot 2) was used for a phosphate test, the effects of lime, of superphosphate, and of rock phosphate, were practically identical on corn. There was no very significant difference in soybeans, but rock phosphate was more effective on the legume-and-grass hay crop. However, none of them used alone produced a satisfactory yield of the latter crop until lespedeza was used in the mixture. Lespedeza gave a large response to both forms of phosphate.

As used in this experiment, there was little difference in the effect of rock phosphate and superphosphate on either limed or

unlimed land, except in the yield of soybean hay on plots 9 and 10 and of second-year hay on plots 6 and 7, for which no explanation is apparent.

The effect of manure (compare plot 1 and plot 3) was quite significant, except on legume-and-grass hay.

The effect of potash was not significant, except that it has shown a fair increase on hay since the rotation was changed. The amount of manure used will not keep up the necessary supply of potash indefinitely. In practical farming, much manure would be dropped on the grass land by grazing animals. It is not possible to pasture these experimental plots. The rate at which manure has been returned is only about two thirds of the production possible from feeding the crops removed.

It is quite likely that on soils like these that have not been drained, potash would produce profitable returns, particularly where manure is not used liberally. Its effect should be tested by farmers generally by applying it liberally on a plot that has been phosphated and comparing it with a similar plot without potash.

Beginning in 1930, plot 2, which had been treated with limestone and manure, was divided and one half of it was treated with superphosphate (16 percent) at the rate of 400 pounds per acre for the rotation period. The other half was treated with an equal weight of 300-mesh rock phosphate. The average yields for these treatments were as follows:

	Superphosphate	Fine rock phosphate
Corn, average 8 crops	46.7 bus.	38.5 bus.
First-year hay, average 7 years	2736 lbs.	2533 lbs.
Second-year hay, average 6 years	2866 lbs.	2605 lbs.

Residual Effect of Phosphates. Beginning in 1930, all plots treated with superphosphate and rock phosphate were divided when they came to corn. On one half of each plot the use of phosphate was continued, and on the other half its use was discontinued. This was done to measure the residual effect of each phosphate. Up to the time of division, approximately 2,750 pounds of superphosphate (16 percent) and twice this weight of rock phosphate (32 percent) had been applied since the beginning of the experiment in 1913. Thus, four times as much phosphorus had been applied in rock phosphate as in

superphosphate, or about 200 pounds of the element phosphorus per acre in superphosphate and 800 pounds in rock phosphate. The ratio of phosphorus applied to date where the use of superphosphate was continued and where rock phosphate was discontinued was approximately 1 to 3. (See page 323 for the average relative prices of these materials for the period 1913–1938.) Manure was returned to both halves of the plot on the basis of crop yields from the omitted half.

The average yields of crops on these divided plots were as follows:

	Corn Ave. 8 crops Bushels	First-year Hay Ave. 7 years Pounds	Second-year Hay Ave. 6 years Pounds
Plot 4 Superphosphate continued	38.1	1943	3002
4a Superphosphate discontinued	39.4	1871	2915
Plot 5 Rock phosphate continued	42.1	2864	3285
5a Rock phosphate discontinued	41.2	2778	3027
Plot 6 Superphosphate continued	44.9	3342	3736
6a Superphosphate discontinued	42.0	2891	3846
Plot 7 Rock phosphate continued	46.0	3522	4205
7a Rock phosphate discontinued	46.4	3617	4262
Plot 9 Superphosphate continued	48.9	3988	4429
9a Superphosphate discontinued	48.0	3359	4089
Plot 10 Rock phosphate continued	48.6	3867	4335
10a Rock phosphate discontinued	49.7	3737	4229
Average of plots 4, 6, 9	44.0	3091	3722
Average of plots 4a, 6a, 9a	43.1	2707	3617
Average of plots 5, 7, 10	45.6	3418	3942
Average of plots 5a, 7a, 10a	45.8	3377	3839

Plots 6, 6a, 7, 7a, 9, 9a, 10, 10a were previously limed.

THE FARISTON SOIL EXPERIMENT FIELD

N. M. Byble, Foreman

The Fariston Soil Experiment Field was established in 1916. It is located about five miles south of London, Laurel County, on U.S. Highway 25.* The soil is a yellow silt loam. It has a rather tight, yellow silty clay subsoil of rather poor drainage. It is derived from shale and sandstone and is fairly typical of a considerable area of land at the base of the coal

* The land for this experiment field was provided by Laurel County, whose helpful cooperation is hereby acknowledged.

measures on the western border of the Eastern Coal Field. The soil is naturally rather unproductive and was very badly worn when work was begun. An analysis of a sample of surface soil from this field gave the following results, stated as pounds in 2,000,000 pounds of soil (the weight of an acre to the depth of about 7 inches):

Total nitrogen	2,300 lbs.
Total phosphorus	820 lbs.
Total potassium	24,400 lbs.
Acidity, strong pH 4.5	

The rotation used on this field until 1922 was corn, soybeans, wheat and clover. After that date, rye was substituted for wheat and clipped and left on the ground unless the clippings were heavy enough to injure the young clover and grass. The soil was poorly adapted to wheat, both on account of its texture and its impoverished condition. The average yield on the best plot for 4 years was 12.1 bushels per acre, there being two failures in the six years. Wheat was restored to the rotation with the crop of 1929. Sorghum for sirup was substituted for corn in 1931-32. Soybeans were dropped from the rotation after 1931, after which the rotation was corn, wheat, and two years of grass-and-legume hay. A rye cover crop followed the corn when wheat was not grown. From 1916 to 1926, the clover sod was plowed immediately after clover harvest and seeded to soybeans or cowpeas, which were either plowed under or disked down (removed from plot 2 from 1920 to 1926), followed by a rye cover crop plowed under before corn. From 1920 to 1924 the cornstalks were left on the ground, except on plot 2. The plan was to use manure regularly after the first round of the rotation on all plots except number 2, but it could not be obtained until 1925, when its use was begun on one half of each plot, for corn. It was used at the rate of 6 tons per acre on the half plots, from 1925 to 1928. It was then applied to the half plots, thru 1932, at rates equal to the weights of the crops removed in the rotation the previous year, wheat grain excepted. Beginning with 1933, manure was applied to the entire plots on the same rate basis. In Table 7 the crop yields are divided into periods. One period shows yields not affected by manure; the second period shows yields affected by manure until the change in the rotation

when soybeans were dropped; the last period shows the yields in the last rotation, all of which were affected by manure. It should be noted that during the last period one half of each plot had been manured longer than the other half because of the previous method of manuring just described.

Superphosphate was used at the rate of 800 pounds of 16-percent grade, or equivalent, per acre, for the four-year rotation, until 1928, when the amount was reduced one half. Bone meal was used to furnish the same amount of phosphorus as in the superphosphate. Rock phosphate (approximately 32 percent grade) was used at twice the rate of superphosphate. Muriate of potash or its equivalent in other potash carriers, was used at the rate of 200 pounds per acre for the rotation, from 1916 to 1932, except that from 1922 to 1927 twice this amount was used.* Since 1932, the rate has been 100 pounds. Limestone was used in three applications of 2 tons each, between 1916 and 1923.** These rates are approximately equal to an annual average rate of 130 pounds of 20-percent superphosphate, 320 pounds of rock phosphate, and 60 pounds of muriate of potash.

One half of the fertilizers, except rock phosphate, was applied for the corn crop and, until 1925, the other half was applied for the third crop (wheat or rye). From 1925 to 1928 the second half was applied for the soybean crop. The second half of the application was changed to wheat, beginning with the 1930 crop, wheat having been restored to the rotation the preceding year. The entire application of rock phosphate was made on the corn ground, except for the first three years when it was applied at the same time as the other fertilizers. The fertilizers were applied on the broken ground and worked in, in preparation of the land for planting (on soybean stubble for wheat and rye), except that some of the applications of rock phosphate were made before plowing.

On plot 15 a 2–8–2 fertilizer was used from 1916 to 1922, inclusive, at the rate of 400 pounds per acre on corn and 400 pounds on the grain crop. Of the application on corn, one half

* The use of extra potash was due to a misunderstanding of plans which arose in the change of superintendents and in changing from a low-grade potash salt to a standard muriate.

** It was intended to use only two applications of limestone, of 2 tons each, but a misunderstanding of plans also arose in the change of superintendents. These errors were not detected until after the publication of Bulletin No. 272 in 1925.

was put in the hill, and one half as a side-dressing or broadcast. The object was to compare superphosphate (plot 8) with an equal weight of a complete fertilizer of this grade. Since the results were no better from this than from superphosphate, the treatment was changed. From 1923 to 1927, instead of the 2–8–2 fertilizer, superphosphate was used on this plot at the same rate as on the superphosphate plots. One hundred pounds of superphosphate, 30 pounds of muriate of potash, and 100 pounds of nitrate of soda per acre were mixed and used in the hill for corn. Beginning with 1928, one half of these amounts was used for corn. In 1923 and 1924 the same application was used on rye (in the fall) as on corn, and from 1925 to 1929 on soybeans, except that the nitrate of soda was left off from 1926 to 1929. Wheat having been restored to the rotation, the second half of the phosphate and potash application was changed to this crop in 1930, with nitrate of soda used at the rate of 100 pounds per acre as a spring top-dressing. The crop yields for the various fertilizer treatments are given in Table 7. The corn crop of 1930 is not included because it was almost a failure on account of drouth.

There were five years in which no clover hay was produced. A crop could not be had the first year, and the crops of 1917, 1924, 1926 and 1936 were failures. The failures are not included in the averages. Clover alone was sown until the crop of 1926, when timothy and common lespedeza were added. Sweet clover was included from 1927 to 1931, and Korean lespedeza from 1928. Common lespedeza was dropped, beginning with the seeding of 1931. Redtop was included from 1928 to 1931, and alfalfa from 1931 to the present. In some of the later years unfavorable for clover, the hay contained a large proportion of grass. Second cuttings of hay have been made frequently in the later years of the experiment, and they are included in the average yields.

Discussion of Results. The outstanding results on this field are the effects of limestone and phosphate used in combination. While each used alone produced fair results, the combination of the two produced increases much greater than the sum of the increases when used separately.

On unlimed soil, rock phosphate was much more effective

Table 7. Average crop yields per acre, Fariston Soil Experiment Field.

Plot No.	Treatment*	Corn, 20 crops, bus.					Soybean hay, 16 crops, lbs.			
		First 9 crops	Next 6 crops	Last 5 crops	20 crops	Increase**	First 10 crops	Next 6 crops	16 crops	Increase
1	M	10.4	17.2	11.2	12.6	———	1350	1770	1508	———
2	O	10.0	4.4	5.6	7.2	—6.2	1403	1227	1337	—284
3	ML	17.9	30.9	26.9	24.0	9.9	2083	3167	2489	755
4	M	10.1	20.4	16.8	14.9	———	1575	2300	1847	———
5	MRp	34.6	39.8	49.6	39.9	26.1	2586	3803	3211	1491
6	MBm	32.5	32.5	36.9	33.6	20.9	2712	3710	3086	1494
7	M	10.5	14.1	10.6	11.6	———	1312	1720	1465	———
8	MP	26.3	26.7	27.7	26.8	16.0	2205	2650	2372	971
9	MPK	28.7	31.5	28.7	29.5	19.4	2272	3353	2678	1342
10	M	7.3	13.2	8.4	9.3	———	1147	1480	1272	———
11	MLP	39.8	53.4	45.9	45.4	35.4	3743	5450	4383	3090
12	MLPK	41.4	50.6	52.6	47.0	36.3	3923	5577	4543	3220
13	M	11.1	13.1	10.1	11.4	———	1309	1377	1334	———
14	MLRp	27.7	42.5	53.3	38.5	26.0	2591	4247	3212	1866
15	MN-P-K	28.4	33.5	40.0	32.8	19.3	2053	2553	2241	883
16	M	9.2	16.2	22.4	14.6	———	1118	1790	1370	———

Plot No.	Treatment*	Wheat 14 crops, bus.		First-year legume-grass hay, lbs., 18 crops					Second-year legume-grass hay, lbs., 5 crops	
		Yield	Increase	First 8 crops	Next 5 crops	Last 5 crops	18 crops	Increase	Yield	Increase
1	M	2.2	———	197	520	76	253	———	000	———
2	O	1.5	—0.9	94	220	000	103	—183	000	———
3	ML	4.7	2.0	505	980	696	690	371	622	602
4	M	2.9	———	227	804	100	352	———	30	———
5	MRp	8.2	5.6	1053	1884	2200	1602	1304	948	901
6	MBm	9.0	6.7	914	1200	2604	1463	1219	1180	1117
7	M	2.0	———	110	408	100	190	———	80	———
8	MP	7.0	4.7	992	960	1323	1076	892	956	866
9	MPK	8.8	6.3	1191	1580	1980	1518	1339	1136	1036
10	M	2.8	———	68	436	80	173	———	110	———
11	MLP	14.2	11.4	2016	3040	6034	3419	3230	4614	4521
12	MLPK	14.2	11.4	2511	3464	7114	4054	3848	4982	4905
13	M	2.8	———	150	484	74	222	———	60	———
14	MLRp	10.3	7.4	1300	2624	8000	3529	3255	5072	5012
15	MN-P-K	9.3	6.4	842	1584	2568	1528	1203	1646	1586
16	M	3.0	———	210	772	250	377	———	60	———

* O = no treatment, M = manure (see page 356 for explanation of use of manure), L = limestone, P = superphosphate, Rp = rock phosphate, Bm = bone meal, K = muriate of potash, N = nitrate of soda. The first 9 crops of corn and the first 9 soybean crops were not affected by manure. The first 8 legume-and-grass hay crops and the first 4 wheat crops were not affected by manure.

**Increases calculated on assumption of uniform variation of soil between check plots before treatment (see page 322).

than superphosphate at the rates used. Bone meal was more effective than superphosphate on unlimed soil and about as effective on the hay crops as rock phosphate.

Limestone was used so heavily in the beginning of the experiment that it depressed the effect of rock phosphate for

many years, but during the last five years limestone and rock phosphate was the most effective treatment on the field. This is perhaps partly explained by the time elapsed since liming, and partly by the greater ability of the two years of grass and legume mixture in the changed rotation to utilize phosphorus from this source than was the case with soybeans and one year of grass and legume mixture. The use of manure in the latter part of the period may have been a factor; also the large accumulated reserve of phosphorus. Approximately 1,000 pounds of phosphorus per acre has been added in the rock phosphate, which is four times the amount added in superphosphate, and more than the surface 7 inches of an acre contained at the beginning of the experiment. No doubt larger returns would have been obtained earlier had not so much limestone been used. More was used than was necessary with superphosphate.

Potash in addition to superphosphate (compare plots 8 and 9) produced a fair increase for the period as a whole. Used in addition to limestone and superphosphate (compare plots 11 and 12), the increase was not significant, except on the grass-and-legume hay. These results indicate that the use of potash in the fertilizer would be profitable unless manure could not be used to the extent possible from a cropping system of this kind. As already explained, manure was not used here during the first nine years.

The "complete" fertilizer (plot 15) on unlimed soil was not significantly better than superphosphate and potash on unlimed soil, except on grass and legume hay in the later years.

It is a safe conclusion that the first investment should be in sufficient limestone and phosphate to be used in a cropping system containing grass and legumes from which as much manure as possible will be saved and returned to the soil.

Beginning in 1928, the plots of the set (No. 3) treated with limestone alone were divided. On one half of each plot an initial application of 1,000 pounds of superphosphate (16 percent) per acre was made for the rotation, after which it was used at the rate of 400 pounds per acre for the rotation, which is the same as

on other superphosphate plots. The average yields on the two halves of the plots for this period were:

	Limestone	Limestone and phosphate
Corn, bus., ave. 8 crops	26.5	47.0
Wheat, bus., ave. 9 crops	4.7	10.3
First-year hay, lbs., ave. 7 crops	771	3769
Second-year hay, lbs., ave. 5 crops	626	2488

Beginning in 1929, the set of plots treated with rock phosphate and the set treated with bone meal were divided, and one half of each plot was treated with very fine dolomitic limestone at the rate of ⅓ ton per acre on wheat each rotation. The average yields of crops for the unlimed and limed halves of these plots were as follows:

	Rp	Rp + L	Bm	Bm + L
Corn, bus., ave. 6 crops	47.4	50.7	37.4	43.2
Wheat, bus., ave. 9 crops	9.2	10.6	8.8	9.3
First-year hay, lbs., ave. 7 crops	2120	2983	2186	2900
Second-year hay, lbs., ave. 5 crops	948	1548	1180	1408

Beginning with the corn crop of 1929 and the wheat crop of 1930, nitrate of soda was used at the rate of 50 pounds per acre at the hill for corn, and at the rate of 100 pounds per acre as a spring top-dressing for wheat on one half of plots 8 and 9. All the plots that were divided for fertilizer treatment were divided at right angles to the direction in which they were divided for manure treatment. Thus, no error was introduced from this source.

The average increase thru 1938 for nitrate of soda thus used was 2.3 bushels of corn, 3.7 bushels of wheat, 417 pounds of first-year hay, and 360 pounds of second-year hay. While the increase of crops was sufficient to return a profit on the use of nitrate of soda, the yields were not nearly so high as on the limed land on which similar amounts of phosphate and potash were used without any nitrate of soda.

THE CAMPBELLSVILLE SOIL EXPERIMENT FIELD

Alva McKinley, Foreman

The Campbellsville Soil Experiment Field was established in 1919.* It is located about one mile northwest of Campbellsville, in Taylor County. The soil is derived from the Waverly

* The land for this field was provided by Taylor County, whose helpful cooperation is hereby acknowledged.

formation, which is made up of limestone and shale. The major or a large portion of the following counties is covered by this formation: Allen, Adair, Barren, Bullitt, Casey, Green, Lewis, Monroe, Rowan, and Taylor. The formation is found in smaller areas in Boyle, Clinton, Cumberland, Estill, Garrard, Jefferson, Larue, Lincoln, Madison, Marion, Menifee, Montgomery, Nelson, Powell, Pulaski, Rockcastle, Wayne, and possibly some other counties.

The soil of this field was in a very unproductive condition when work was begun. The average of the analyses of a number of samples from the field shows the soil to contain approximately the following amounts of nitrogen, phosphorus and potassium in 2,000,000 pounds of soil (the weight of an acre to the depth of about 7 inches):

Total nitrogen	2,375 lbs.
Total phosphorus	1,100 lbs.
Total potassium	13,000 lbs.
Acidity, moderate, pH 5.5	

In this area are found numerous marl deposits that are weathering and supplying lime to soils on the slopes below them. No doubt old beds have weathered out and affected the reaction of the soil in many places where deposits do not now appear. The weathering of these marls doubtless explains the successful growing of red clover, sweet clover and alfalfa without liming often reported from this area.

On the Campbellsville field three series of nineteen plots each were devoted to a general fertilizer test in a rotation of corn, wheat and clover. Three series of sixteen plots each were used for a test of rates of application of superphosphate and rock phosphate in a rotation of corn, wheat and clover.

In both tests a mixture of red and alsike clover was used for the third-year crop, thru 1924. Timothy was introduced in 1925 (year of harvest), common lespedeza in 1926, alfalfa in 1927, and Korean lespedeza in 1928. Each of these was continued in the mixture from the time it was introduced, except common lespedeza, which was left out beginning with the seeding of 1931, and alsike clover, which was left out beginning with the seeding of 1933. The cropping in 1919 was preliminary, and no yields are included for that year.

The General Fertilizer Tests. Fertilizers and limestone were used as follows:

Limestone at the rate of 2 tons per acre twice between 1919 and 1924.

Superphosphate (16 percent) at the rate of 600 pounds per acre for the rotation thru 1930, after which the rate was 300 pounds, or its equivalent of 20 percent grade. These applications are equal to an average annual rate of 160 pounds per acre of 16 per cent grade.

Basic slag in amounts to furnish approximately the same amount of phosphorus as the superphosphate.

Muriate of potash or its potash equivalent, at the rate of 150 pounds per acre for the rotation thru 1930, after which it was 75 pounds. This is equal to approximately 40 pounds per acre per year.

Nitrate of soda at the rate of 100 pounds per acre for corn and 100 pounds per acre for wheat thru 1930, after which the rate for corn was 50 pounds per acre, applied at the hill at planting time.

All materials except nitrate of soda were applied broadcast after breaking the ground for corn, and disked in, except that for a brief period following the war when potash was scarce, the application was divided between corn and wheat. The nitrate of soda was applied around the corn hills, between planting time and when corn was a few inches high, thru 1928. (See page 368 for change in method.) The application to wheat was made when growth began in the spring. Beginning in 1937, the phosphate and potash were applied to wheat instead of corn (see page 346).

It was planned to begin the return of manure in 1923, with the second round of the rotation, but manure could not be obtained at that time. Its use was begun in 1926, when it was applied on all plots except number 2, at the rate of 5 tons per acre, on the corn ground. It was used in the same manner at 6 tons per acre in 1927, and 5 tons per acre in 1928. Beginning with 1929, manure was applied to all plots except number 2, at the rate of 1 ton for each ton of produce removed from the corresponding plots the preceding year, wheat grain excepted.

In 1919, cowpeas and soybeans were grown and turned

under on the series that grew corn in 1920. A light growth of crimson clover was turned under for the corn crop of 1921. In 1923 and 1924 the clover crops were almost failures and were left on the ground, followed by cowpeas which were plowed under for the benefit of the corn crops of 1924 and 1925. After clover harvest in 1925, the ground was seeded to soybeans, which were turned under. The crop yields in this test are given in Table 8.

Corn was almost a failure in 1930, due to drouth, and is not included. Wheat was a failure in 1920, 1924 and 1928, due partly to unfavorable winters. The earlier failures no doubt were due in part to the impoverished condition of the soil. The first clover crop attempted (1920 crop) was a failure. Also, as already stated, the clover crops of 1923 and 1924 were failures. The clover and grass crop for 1926 failed, but lespedeza in the mixture reseeded itself in 1925 and made a good growth. It is probable that these clover failures were due to the use of an unadapted strain. A Kentucky-grown adapted strain has been sown beginning with the crop of 1929. Crop failures are not included in the averages. Second cuttings were obtained several times and are included in the average yields.

In the first period in the table the crop yields are given for the period before the fertilizer applications were reduced. The second period is for the time of the reduced applications and coincides with the period of discontinued use on the plots of the phosphate test where 900 pounds of superphosphate and 1,800 pounds of rock phosphate per rotation had been used.

The Phosphate Tests. Limestone, fertilizers and manure were used in the same way as in the general fertilizer test (see page 363), except for the amounts of phosphate applied. In table 9 the figures in parentheses show the rates thru 1930. Beginning with 1931, the 1,200-pound rate for rock phosphate was reduced to 600 pounds. Where the 900-pound rate for superphosphate and the 1,800-pound rate for rock phosphate were used, none has been applied since 1930. This was for the purpose of studying the residual effect of these heavy applications. The last period of crop yields in the table coincides with the period of reduced application and omission. The 300-pound rate for superphosphate and 600-pound rate for rock phosphate

Table 8. Average crop yields per acre, general fertilizer test, Campbellsville Soil Experiment Field.

Plot No.	Treatment*	Corn, bus., 18 crops				Wheat, bus., 16 crops				Hay, lbs., 16 crops			
		First 10 crops	Last 8 crops	18 crops	Increase**	First 9 crops	Last 7 crops	16 crops	Increase	First 10 crops	Last 6 crops	16 crops	Increase
1	M	23.5	37.6	29.7	.....	6.0	4.8	5.5	.....	965	1763	1264	.....
2	O	14.7	13.7	14.2	—14.2	2.6	1.0	1.9	—2.9	646	767	691	—515
3	ML	29.8	32.5	31.0	4.0	6.7	4.3	5.7	1.5	1299	1593	1409	260
4	M	22.4	29.9	25.7	.....	3.8	3.1	3.5	.....	871	1458	1091	.....
5	MP	46.4	61.0	52.9	23.0	11.0	11.9	11.4	7.0	2612	3437	2921	1588
6	MPK	48.1	63.2	54.8	20.8	12.3	12.0	12.1	6.9	2648	3785	3074	1500
7	M	33.2	44.6	38.2	.....	6.8	5.1	6.1	.....	1339	2612	1816	.....
8	MPN	52.3	64.1	57.5	20.3	14.8	15.2	15.0	9.2	2707	3777	3108	1241
9	MPKN	52.2	66.4	58.5	22.4	15.4	16.7	16.0	10.6	2877	4322	3419	1501
10	M	28.3	43.6	35.1	.....	5.4	4.6	5.1	.....	1456	2823	1969	.....
11	MBsKN	50.5	61.8	55.5	21.6	15.3	16.9	16.0	10.9	2937	4750	3617	1752
12	MLP	53.4	63.5	57.9	25.3	13.1	16.0	14.3	9.2	3209	4995	3879	2119
13	M	25.9	38.3	31.4	.....	5.4	4.8	5.1	.....	1226	2373	1656	.....
14	MLPK	54.7	65.0	59.3	26.8	14.8	18.1	16.3	10.7	3395	5392	4144	2448
15	MLPN	54.5	60.0	56.9	23.3	16.9	18.9	17.8	11.8	3198	5253	3969	2234
16	M	29.2	41.7	34.7	.....	6.4	6.5	6.5	.....	1240	2667	1775	.....
17	MLPKN	54.7	61.3	57.6	23.9	17.3	19.8	18.4	12.1	3534	6088	4492	2798
18	MLBsKN	52.4	60.2	55.9	23.3	17.4	19.1	18.2	12.2	3168	5570	4069	2455
19	M	25.4	39.5	31.6	.....	5.9	5.6	5.8	.....	1002	2418	1533	.....

* M = manure, L = limestone, P = superphosphate, Bs = basic slag, K = muriate of potash, N = nitrate of soda.

** Increase calculated on assumption of uniform variation of soil between check plots before treatment. (See page 322.)

were continued thru 1938. At the end of 1938 the average annual rates of the various phosphates applied per acre and the content of phosphoric acid (P_2O_5) were as follows:

Plots 2 and 8, superphosphate,	100 lbs. containing	16 lbs.	P_2O_5
Plots 3 and 9, rock phosphate,	200 lbs. containing	64 lbs.	P_2O_5
Plots 5 and 11, superphosphate,	180 lbs. containing	29 lbs.	P_2O_5
Plots 6 and 12, rock phosphate,	360 lbs. containing	115 lbs.	P_2O_5
Plots 14 and 15, rock phosphate,	320 lbs. containing	102 lbs.	P_2O_5

Plots 14 and 15 are to be compared with plots 5 and 12 in Table 8, which received superphosphate at the rate of 160 pounds per acre per year (26 pounds P_2O_5).

The rock phosphate was applied on the unbroken corn ground and plowed under, thru 1925; after that, on the broken ground. Cowpea or soybean catch crops were used in this rotation as in the general fertilizer test. The crop failures occurred at the same time in this test as in the general fertilizer test, except that a light clover crop was harvested in these tests in 1923 when the crop was a failure in the general fertilizer tests. In 1924, fire caught in the dead grass and weeds on part of a number of plots and so injured the clover that it was plowed up and the plots seeded to cowpeas, which were turned under. Lespedeza was harvested in 1926, and the yields are included in the hay average, as in the general fertilizer test. In 1935, the first cutting of hay was ruined by rains and not weighed, whereas it was saved in the general fertilizer test. Second cuttings of hay were obtained several times and are included in the averages.

Discussion of Results. The outstanding results on this field are the effects of limestone and phosphates in increasing yields. If only one of the two can be used, phosphate is far the more important. Limestone used alone produced small increases, but used in addition to superphosphate it was profitable. Where limestone was used with rock phosphate, the combination gave lower yields than rock phosphate alone in the first twelve years of the experiment. Shortly after 1930 the combination began to give better results, particularly on hay, as will be observed in the yields of the second period (Table 9). Too much limestone was used with the rock phosphate, and it depressed the effectiveness of the rock phosphate.

On unlimed ground, rock phosphate used at twice the rate of superphosphate gave better results than superphosphate. This is not true on the limed ground, because it was limed too

Table 9. Average crop yields per acre, phosphate tests, Campbellsville Soil Experiment Field.

Plot No.	Treatment*	Corn, bus., 18 crops				Wheat, bus., 16 crops				Hay, lbs., 17 crops			
		First 10 crops	Last 8 crops	18 crops	Increase**	First 9 crops	Last 7 crops	16 crops	Increase	First 11 crops	Last 6 crops	17 crops	Increase
1	M	21.3	34.6	27.2	.....	5.4	5.4	5.4	.....	1128	2174	1497	.....
2	M(P300)	37.3	53.8	44.6	14.8	9.9	11.3	10.5	4.7	1959	3134	2374	707
3	M(Rp600)	41.8	58.9	49.4	17.1	11.6	13.7	12.5	6.4	2642	4078	3149	1311
4	M	29.6	41.7	34.9	.....	7.1	5.6	6.5	.....	1575	2802	2008	.....
5	M(P900)	47.8	60.2	53.3	18.5	14.4	12.5	13.6	7.2	3292	3838	3485	1493
6	M(Rp1800)	49.7	60.3	54.4	19.8	14.8	16.0	15.3	8.9	3888	4808	4213	2236
7	M	30.0	40.2	34.5	.....	6.6	6.0	6.3	.....	1463	2874	1961	.....
8	ML(P300)	44.3	54.3	48.7	14.5	12.6	14.8	13.6	7.2	2444	3952	2976	1077
9	ML(Rp600)	37.6	55.5	45.6	11.8	10.1	13.7	11.7	5.2	2388	4818	3245	1408
10	M	29.7	38.2	33.5	.....	6.8	6.3	6.6	.....	1348	2558	1775	.....
11	ML(P900)	54.2	60.1	56.8	23.1	17.1	15.9	16.6	9.8	4033	4632	4244	2378
12	ML(Rp1800)	44.0	56.2	49.4	15.6	12.8	16.8	14.6	7.6	3320	5402	4055	2098
13	M	28.7	40.5	34.0	.....	7.2	7.1	7.2	.....	1546	2968	2048	.....
14	M(Rp1200)	46.1	61.7	53.0	18.9	13.5	15.1	14.2	6.8	3778	5160	4266	2280
15	ML(Rp1200)	40.4	60.5	49.3	15.0	11.6	17.4	14.2	6.5	2851	5398	3750	1826
16	M	28.0	42.4	34.4	.....	8.1	7.6	7.9	.....	1391	2726	1862	.....

* M = manure, L = limestone, P = superphosphate, Rp = rock phosphate. Figures in ( ) indicate pounds applied per acre per rotation thru 1930. Modifications since 1930 were: no phosphate used on plots 5, 6, 11 and 12; the rate on plots 14 and 15 reduced one-half. The full rates continued on plots 2, 3, 8 and 9.

** Increases calculated on assumption of uniform variation of soil between check plots before treatment. (See page 322.)

heavily for the most effective use of rock phosphate. The residual effect of rock phosphate and superphosphate is significant, as will be seen from continued high yields since those fertilizers were omitted in the last period on plots 5, 6, 11 and 12, Table 9. Basic slag on unlimed ground had about the same total effect as superphosphate, with a slight difference in hay in favor of basic slag, while on limed ground there was a slight difference in hay in favor of superphosphate.

As an average of all tests, potash had practically no effect on corn and wheat, but increased the yield of hay about 300 pounds per acre, the increase being decidedly greater for hay in the last period. The manure probably met the needs of corn and wheat for potash, but not for the hay crop which is the farthest removed from the application of the manure.

Nitrate of soda had practically no effect on corn. It increased the yield of wheat an average of 2.5 bushels per acre for 100 pounds used as a top-dressing in the spring. There was, on the average, no significant effect of the top-dressing on the hay following the wheat.

Hill Application Tests of Fertilizers for Corn. From 1929 to 1936 the fertilized plots in the general fertilizer tests (Table 8) were divided. On one half of each plot all the phosphate and potash was applied broadcast as had been done previously for the entire plot. For the other half of the plot, 100 pounds of superphosphate and 15 pounds of muriate of potash were reserved to be applied at the hill for corn, while the remainder of these materials was applied broadcast as on the other half of the plot. On those plots where nitrate of soda was used, the rate for corn was 50 pounds per acre (except that 100 pounds were used in 1929). All the materials for the hill application were mixed before applying. Where all three materials were used for hill application, the mixture was equivalent to 200 pounds per acre of a 4–8–4 fertilizer. Where phosphate and potash were used, the mixture was equivalent to 200 pounds of 0–8–4 fertilizer. To be exact, the potash in the mixtures was equivalent to 3.75 percent in a 200-pound mixture. Where nitrate of soda was used on the "all-broadcast" half of the plot, it was applied at the hill. For five years the mixture was placed in the furrow at the hill in a strip about

3 to 4 inches wide and 10 inches long, and mixed with the soil with a hoe. For the next three years a device was used which placed the fertilizer in bands about 8 inches long on each side of the hill, about 3 inches from the seed and 1 inch below the seed. The all-broadcast half and the hill-application half of the plots were alternated by three-year periods. There was no significant difference in the effect on yield of the two methods of application where no nitrate of soda was used, but it was thought some injury was detected now and then from the nitrate of soda before the fertilizer was placed in bands at the sides of the hill. The crop of 1930 was a failure on account of drouth and is not included in the averages. The average yields of corn, in bushels per acre, for the two methods of hill application and for broadcast application were as follows.

Fertilizer mixed with the soil in hill (Four-year average)

	All-broadcast application	Hill application		All-broadcast application	Hill application
P	58.5	55.8	PN	61.5	59.4
PK	58.7	57.7	PKN	62.0	60.0
LP	65.6	64.5	LPN	57.1	58.3
LPK	67.4	64.7	LPKN	59.9	54.2
Ave.	62.5	60.7		60.1	58.0

Fertilizer in bands at sides of hill (Three-year average)

	All-broadcast application	Hill application		All-broadcast application	Hill application
P	61.1	60.9	PN	66.0	65.4
PK	64.3	62.7	PKN	67.8	68.8
LP	65.2	62.1	LPN	64.4	65.0
LPK	66.6	66.4	LPKN	66.5	64.8
Ave.	64.3	63.0		66.2	66.0

It would seem from these tests that where phosphate and potash are used regularly in a rotation, and manure is used for corn, as was done in this experiment, there is no advantage in hill application of phosphate and potash.

Tobacco Experiments. There is a tobacco experiment on this field, the results of which were published in Bulletin 379 (1938).

THE GREENVILLE SOIL EXPERIMENT FIELD

C. R. Lovell, Foreman

The Greenville Soil Experiment Field was established in 1913.* It lies about two miles west of Greenville, in Muhlenberg County. The soil is classed as Tilsit silt loam, and fairly represents the uplands of the Western Coal Field and the sandstone area on its borders. It is derived from interbedded shale and sandstone. An analysis of a sample of surface soil of this field gave the following results, stated as pounds in 2,000,000 pounds of soil (the weight of an acre to the depth of about 7 inches):

Total nitrogen	1,780 lbs.
Total phosphorus	660 lbs.
Total potassium	24,600 lbs.
Acidity, moderate, pH 5.5	

Two sets of fertilizer experiments are conducted on this field. One is with tobacco, the results of which were reported in Bulletin 379 (1938). The other experiments are in a four-year rotation, which was corn, soybeans, wheat, and legume-and-grass hay for the fourth year, thru 1931, after which it was changed to corn, wheat, and two years of mixed legume and grass hay.

The Four-year Rotation. The land occupied by this rotation has very poor natural drainage. A tile drainage system was put in in the spring of 1916. The lines of tile are in the roadways, 120 feet apart, and are fairly effective.

Limestone was used at the rate of 2 tons per acre per rotation twice between 1913 and 1920, except that on one series one application was at the rate of 4 tons per acre. The limestone was applied on the series for corn, except that fractional applications were used on the other series the first year, as at Berea. These applications made an average of 5.25 tons per acre in twenty-six years. The limestone was screenings of ¼ inch and finer. In 1933 a portion of some of the previously limed plots was relimed at the rate of 1 ton per acre, but without observable effect on the growth of succeeding crops.

Superphosphate (16 percent or its equivalent) was used at the rate of 800 pounds per acre for the four-year rotation period, for two rounds of the rotation, after which the rate was reduced

* The land for this experiment field was provided by Muhlenberg County, whose helpful cooperation is hereby acknowledged.

to 400 pounds per acre. Rock phosphate was used at double the rate of superphosphate.

Muriate of potash, or its potash equivalent, was used at the rate of 400 pounds per acre for the rotation for the first three years, and 200 pounds per acre per rotation thru 1930, after which the rate was 100 pounds. An exception to this is plot 6, which was amended in 1916 by the addition of muriate of potash, beginning with the 200-pound rate.

Total applications of the various fertilizing materials are equivalent to annual applications of approximately the following amounts: superphosphate (16 percent), 135 pounds, or 110 pounds of 20-percent grade; rock phosphate (32 percent), 270 pounds; muriate of potash or its equivalent, 50 pounds.

The fertilizers were applied on the corn ground in the full amount for the rotation until 1924–26, when the applications were changed to the wheat ground except that in 1933–36 part of the phosphate and potash were used in the hill for corn. Fractional applications were used the first year as in the case of limestone. An exception was plot 6, on which one third of the application of phosphate was applied on each of the first three crops from 1913 to 1916, when the treatment was amended by adding potash, as already stated. Fertilizers and limestone were applied on the broken ground and disked in, until the change was made to wheat, except that the rock phosphate usually was applied before breaking.

A cowpea crop was grown on Series 200 in 1913, in lieu of clover, and was plowed under for the corn crop of 1914. Manure was used at the rate of 6 tons per acre, on the corn land, on all plots except number 1, from 1916 to 1919, inclusive. From 1920 to 1924 the cornstalks were left on the ground, and the wheat straw was returned to the corn ground of the next year (except plot 1). Since 1924, manure was used on all corn plots, except number 1, at a rate equal to the weight of crops removed from the corresponding plots the preceding year (wheat grain excepted), except in 1927 and 1928, when it was used at a uniform rate based on the weight of the crops removed from the check plots the preceding year. It was planned to use manure regularly from 1916 on, but it could not always be obtained. In 1923 and 1924, after harvesting the clover crops, which were poor, the ground was planted to cowpeas which were disked in and followed by rye.

Corn was so nearly a failure in 1913 that it was not husked. The 1930 crop practically failed because of drouth, and is not included in the averages. Soybeans were harvested for seed in 1915 instead of for hay. Wheat could not be sown for the 1920 and 1926 crops on account of wet weather the previous fall. The first clover crop was harvested in 1915. The crop for 1925 was winterkilled. Soybeans were substituted and harvested for hay. In 1928 clover was a failure on all except plots 11 and 13, which made 500 and 700 pounds per acre, respectively. However, lespedeza was used in the mixture and made a fairly good crop of hay, making 2,490 pounds per acre on the best plot (No. 6).

Other plants have been included with clover (red and alsike) as follows (year of harvest given):

1916	Orchard grass and tall meadow oat grass
1917	Sweet clover and timothy
1918-19	Sweet clover
1921	Timothy
1926	Common lespedeza and timothy
1927	Common lespedeza, timothy and alfalfa
1928	Common and Korean lespedeza, alfalfa, timothy

All additions since 1926, inclusive, have been continued to the present, except common lespedeza and alsike clover, which were dropped in 1932 and 1935, respectively.

The crop yields for the various fertilizer treatments are given in Table 10. The yields are given in two periods for the time before the rotation was changed, and for one period after the rotation was changed. Yields are not given for plots 6, 9 and 11 for the first period because the treatments were changed in 1916. Potash was added to plot 6, which previously received only superphosphate. Superphosphate was added to plot 9 previously treated with potash, and to plot 11 previously treated with limestone and potash. (See Bulletins 228 and 272 for yields of these plots to 1925.) Five series of plots were used for this rotation most of the time, Series 100 and 500 having the same crop.

Beginning in 1929, the set of plots (No. 2) previously treated with limestone at the rate stated on page 370 was divided, and one half of each was treated with 300-mesh rock phosphate at the rate of 2,000 pounds per acre. None has been added since.

Table 10. Average crop yields per acre, Greenville Soil Experiment Field.

Plot No.	Treatment*	Corn, bus., 24 crops						Soybean hay, lbs., 18 crops			
		First 9 crops	Next 10 crops	Last 5 crops	24 crops	Last 15 crops	Increase last 15 crops**	First 9 crops	Last 9 crops	18 crops	Increase last 9 crops
1	O	19.4	14.4	14.0	16.2	14.3	—15.0	1242	1609	1426	—712
2	ML	32.1	28.9	37.2	31.8	31.7	2.4	2269	2444	2356	123
3	M	29.5	26.6	34.7	29.4	29.3	.....	1709	2321	2015	.....
4	MP	34.8	41.2	47.0	40.0	43.1	13.8	2462	3369	2915	1048
5	MRp	34.8	44.1	50.7	42.0	46.3	17.0	2573	3529	3051	1208
6	MPK	.....	44.2	48.0	.....	45.5	16.2	.....	3366	.....	1045
7	MLP	42.3	47.3	50.9	46.1	48.5	20.8	3312	3674	3493	1501
8	MLRp	37.8	46.5	51.7	44.3	48.2	20.5	2835	3528	3182	1355
9	MPK	.....	42.9	46.3	.....	44.0	16.3	.....	3008	.....	835
10	M	23.3	25.2	32.7	26.0	27.7	.....	1639	2173	1906	.....
11	MLPK	.....	52.1	54.8	.....	53.0	25.3	.....	3868	.....	1695
12	MRpK	38.2	52.0	56.7	47.8	53.5	25.8	2855	3894	3375	1721
13	MLRpK	41.8	56.4	59.9	51.7	57.6	29.9	3143	3934	3544	1761

Plot No.	Treatment*	Wheat, bus., 23 crops					1st-year grass-legume hay, lbs., 23 crops					2d-year, grass-legume hay, lbs., 5 crops	
		First 8 crops	Next 8 crops	Last 7 crops	Last 15 crops	Increase 15 crops	First 8 crops	Next 9 crops	Last 6 crops	Last 15 crops	Incr. 15 crops	Yield	Incr.
1	O	2.9	1.8	3.1	2.4	—4.1	420	458	1451	855	—716	958	—1025
2	ML	7.1	6.0	9.4	7.6	1.1	1685	790	2580	1506	—65	2150	167
3	M	5.7	4.2	9.1	6.5	.....	1055	769	2774	1571	.....	1983	.....
4	MP	9.0	12.6	18.4	15.3	8.8	2352	2518	4113	3156	1585	3338	1355
5	MRp	9.7	16.0	20.9	18.3	11.8	2612	3071	5133	3896	2325	3880	1897
6	MPK	.....	14.6	20.9	17.5	11.0	.....	2762	4998	3657	2086	3726	1743
7	MLP	13.5	19.6	22.6	21.0	15.0	2875	3409	4932	4018	2492	4036	2360
8	MLRp	10.6	16.4	20.8	18.5	12.5	2250	3084	5055	3873	2347	4432	2756
9	MPK	.....	13.6	19.5	16.4	10.4	.....	2386	4985	3425	1899	3366	1690
10	M	5.9	4.7	7.5	6.0	.....	512	813	2595	1526	.....	1676	.....
11	MLPK	.....	18.7	22.7	20.6	14.6	.....	3702	5497	4420	2894	3942	2266
12	MRpK	11.6	18.8	21.5	20.1	14.1	3152	3785	6680	4943	3417	4379	2703
13	MLRpK	11.9	18.2	21.7	19.8	13.8	2989	3966	6758	5083	3557	5620	3944

* L = limestone, M = manure, P = superphosphate, Rp = rock phosphate, K = muriate of potash.
** Plots 3 and 7 are used for check plots. Increases were determined by comparison with the nearest check plot.

Each half was manured for corn on the basis already described (page 371). The average yields of crops for the two halves of the plots since division were:

	Limestone	Limestone and 300-mesh rock phosphate
Corn, bus., ave. 9 crops	36.0	48.3
Wheat, bus., ave. 9 crops	9.4	15.9
First-year hay, lbs., ave. 8 crops	2258	4176
Second-year hay, lbs., ave. 5 crops	2150	4150

Beginning with the seeding of wheat in 1928, plots number 4, treated with superphosphate at the rate stated on page 370, were divided and one half of each was treated with ⅓ ton of very fine limestone when wheat was sown. No more has been used since. The average yields of crops for the two halves were as follows:

	Super-phosphate	Fine limestone and super-phosphate
Corn, bus., ave. 8 crops	49.2	51.2
Wheat, bus., ave. 10 crops	17.8	18.7
First-year hay, lbs., ave. 9 crops	3686	4062
Second-year hay, lbs., ave. 5 crops	3338	3686

Beginning with 1931, plots 7 (LP), 8 (LRp) and 13 (LRpK) were divided into halves when they came to wheat, and the phosphate treatment was left off one half (designated 7a, etc.) and continued on the other half at the rate stated on page 370-371. The average yields of crops for the period on the two halves were as follows:

Plot	Treatment	Corn	Wheat	Hay	
	All plots limed	average of 6 crops	average of 8 crops	1st year, average of 7 crops	2nd year, average of 5 crops
		bushels	bushels	pounds	pounds
7	P used	53.4	24.0	4554	4036
7a	P discountined	52.3	20.1	4171	3924
8	Rp used	55.1	22.4	4801	4432
8a	Rp discontinued	54.2	21.6	4851	4320
13	RpK used	62.4	22.9	6207	5620
13a	Rp discontinued	64.9	23.9	5957	5568

Where both phosphates were used thruout the experiment, the ratio of phosphorus applied in twenty-six years, in superphosphate and in rock phosphate, was 1 to 4. As between super-

phosphate continued and rock phosphate discontinued, the ratio for twenty-six years was approximately 1 to 3. (See page 323 for the average relative prices of the two materials thruout the period, 1913 to 1938.)

Use of Nitrate of Soda on Corn and Wheat. Beginning in 1929, plots 6 (MPK), 9 (MPK) and 11 (MLPK) were divided in halves lengthwise. On one half of each plot nitrate of soda was used for corn, applied at the hill at planting time, at the rate of 50 pounds per acre. As an average for the three sets of plots and nine crops of corn, nitrate of soda increased the yield only 0.4 of a bushel. The largest increase for any one set of plots (9) was 1.1 bushels per acre.

The wheat on one half of plots 6 and 9 was treated with 50 pounds of nitrate of soda per acre at seeding time. The average of the treatment for nine crops and the two sets of plots was an increase of 1.2 bushels per acre. The wheat on one half of plots 11 was top-dressed with 100 pounds of nitrate of soda per acre in the spring. As an average of ten crops the yield was increased 3.6 bushels per acre by the treatment.

The yield of first- and second-year hay was somewhat less following wheat treated with nitrate of soda in the fall. The yield of first-year hay following wheat top-dressed in the spring was approximately 500 pounds per acre greater than on the half that was not top-dressed, and the increase for second-year hay was slightly less than 100 pounds.

Discussion of Results. There are not enough check plots in this experiment to make it possible to evaluate small differences between treatments. That plots 12 and 13, and probably 11, were naturally more fertile than the other plots when the experiments were begun has been pretty well established. After work was begun on the field and the variation in fertility was observed, an inquiry among old residents of the neighborhood disclosed that a fence at one time ran across the field about where plots 11 are located, and that the side where plots 12 and 13 were located was newer ground. The land had quite a uniform appearance when examined for the location of the experiments. However, certain results are so outstanding that soil variations cannot invalidate them. One is the large effect of phosphates. Another is that limestone used alone had little

effect, but that where used with superphosphate it was quite effective from the beginning of the experiment. Limestone used with rock phosphate was not so effective as when used with superphosphate. It was used at too heavy a rate and probably interfered with the effectiveness of the rock phosphate. As time passed after liming was discontinued, rock phosphate tended to become relatively more effective on limed ground. Rock phosphate compared very favorably with superphosphate at the rates used in these comparisons.

An interesting result is the effect of the continued use of the phosphates as compared with the residual effect of the phosphates where their use was discontinued (see page 374). These comparisons will be continued for some time to determine the lasting effect of reserves of phosphate built up in the soil by the use of the two forms. Where both phosphates were used for the same length of time, four times as much phosphorus was added in the rock phosphate as in the superphosphate. Where the rock phosphate was discontinued and the superphosphate was continued, the relative amounts of phosphorus added were approximately 3 to 1.

The effect of potash is difficult to determine because soil variation makes the size of the apparent increase of somewhat questionable significance. However, it is believed that this increase is of some significance, particularly on hay, where the effect increases with the age of the experiment. With the yields of hay much increased with the age of the experiment, the manure returned, which fairly meets the needs of corn and wheat for potash, probably does not carry over enough potash to meet the needs of the hay crop. On land where yields are low because lime and phosphate are the first limiting factors, the draft on potash is not very heavy before treating with lime and phosphate; consequently, in the first years after using lime and phosphate the potash supply may be sufficient for a while. However, with the increased yields from the use of lime and phosphate, a much heavier draft is made upon potash and, unless all crop residues and manure are saved and returned, a deficiency of potash will sooner or later occur. In this experiment there were eight years when no manure was returned. For most of the time manure was used, it was used at the rate of 1 ton for each

ton of produce removed in the crops of the rotation in the previous year, wheat grain excepted. The actual production of manure is about one and one half tons for each ton of feed and bedding used. The 1-ton equivalent was used because it was thought to be more in line with practical farm conditions. However, in farm practice animals drop considerable manure on pastures, whereas in experiments like this pasturing of plots is not practicable.

It is advised that farmers make field tests of the application of potash according to directions which will be sent on application. Field tests carefully made are much more reliable as a guide as to the need of potash than a chemical test.

For further data on the effect of potash on crops on this field, see Bulletin 379, which gives the results in tobacco rotations.

THE MAYFIELD SOIL EXPERIMENT FIELD

J. L. Payne, Foreman

The Mayfield Soil Experiment Field was established in 1913.* It lies about two miles southwest of Mayfield, in Graves County. It was intended to represent as nearly as could be determined at that time the upland soils of the Purchase region. A soil survey had not been made in the county at that time. According to a recent soil survey,† about 95 percent of the area on which the plots are located is Grenada silt loam, and the remaining 5 per cent is of similar types. Grenada silt loam is the most extensive type in the Purchase region. The response to treatment on this field should be a safe guide for treatment of most of the upland soils of this region. An analysis of the surface soil of this field at the time work was begun gave the following results, stated as pounds in 2,000,000 pounds of soil (the weight of an acre to the depth of about 7 inches):

Total nitrogen	1,920 lbs.
Total phosphorus	960 lbs.
Total potassium	29,700 lbs.
Acidity, strong, pH 4.9	

* The land for this experiment was provided by Graves County, whose helpful cooperation is hereby acknowledged.

† This survey is being made cooperatively by the United States Bureau of Soils, the Tennessee Valley Authority, and the Kentucky Agricultural Experiment Station.

The Four-year Rotation. Two sets of fertilizer experiments are conducted on this field. One is with tobacco, the results of which were reported in Bulletin 379 (1938). The other experiments are in a four-year rotation, which was corn, soybeans (winter oats was used in the place of soybeans in 1914 and 1915), wheat and legumes and grass for the fourth year, thru 1931, after which it was changed to corn, wheat and two years of mixed grass and legume hay.

As the first series of plots was later dropped from the rotation because of variation in productivity, and another substituted for it, the crop yields from this series are omitted. This eliminates only one corn crop, two wheat crops, and one clover crop.

Limestone was used at the rate of 2 tons per acre per rotation for two rounds of the rotation, 1913-1920. It was applied on the series for corn, except that fractional applications were used on the other series the first year, as at Berea (page 351). These applications amounted to an average of 4.5 tons of limestone per acre in twenty-six years. The limestone was screenings of ¼ inch and finer. Recent reliming tests do not show a need for reliming.

Superphosphate (16 percent or equivalent) was used at the rate of 800 pounds per acre for the four-year rotation for two rounds of the rotation, after which the rate was reduced to 400 pounds. Rock phosphate was used at double the rate of superphosphate. The rock phosphate was approximately 32 percent grade.

Muriate of potash, or its potash equivalent, was used at the rate of 400 pounds per acre for the rotation, the first three years; then 200 pounds per acre per rotation thru 1930, after which the rate was 100 pounds.

All the fertilizers were applied on the corn ground in the full amount for the rotation until 1924-26, when the applications were changed to the wheat ground, except that in 1933–36 part of the phosphate and potash were used in the hill for corn. Fractional applications were used the first year as with limestone. Plot 9 is an exception to this statement. On this plot the superphosphate application for the rotation was divided into three equal parts and applied on the first three crops of the rotation thru 1920, after which it was applied as on the other plots. These fertilizers were applied on the broken ground and disked into the

soil until the change was made to wheat, except that the rock phosphate usually was applied before breaking.

Nitrate of soda was used at the rate of 100 pounds per acre on corn, except that dried blood was used instead of nitrate of soda for the first three years and in addition to it for the next two years. These nitrogen materials were applied broadcast part of the time in the earlier years of the experiment and the remainder of the time, thru 1932, around the hill and between planting time and the second cultivation. Since then the nitrate of soda has been applied at the hill at planting time, at the rate of 50 pounds per acre. Nitrate of soda was used on wheat at the rate of 100 pounds per acre, applied at the beginning of spring growth.

The total applications of phosphate and potash were equivalent to average annual applications of approximately 140 pounds of 16-percent superphosphate (or 112 pounds of 20-percent grade), 280 pounds of rock phosphate, and 54 pounds of muriate of potash.

Cowpeas were grown on series 200 in 1913, instead of clover, and were turned under for the corn crop of 1914.

Manure was used at the rate of 6 tons per acre, on the corn land, on all plots except Nos. 1 and 10, from 1916 to 1919, inclusive. No manure was used in 1920. Since then it has been applied to the corn plots receiving manure, at a rate equal to the weight of the crops removed from the corresponding plots the preceding year (wheat grain excepted), except in 1927 and 1928 when it was used at a uniform rate equal to the average weight of crops removed from the check plots the preceding year.

Plot 1 did not receive manure or crop residues. From 1916 to 1919, inclusive, cornstalks and straw were returned to plot 10. Since then no manure or residues have been returned to this plot, which is used in comparison with plot 9 to measure the effect of manure.

The corn crop of 1919 was ruined for experimental purposes by cattle that broke into the field. The crop was almost a failure in 1930 on account of drouth and is not included in the averages. Soybeans were not introduced into the rotation until 1916. Before then, winter oats occupied the second year in the rotation. Wet weather in the falls of 1919 and 1925 prevented seed-

ing wheat, and the crop was partially destroyed by chickens in 1923.

The clover crop of 1917 was the first used in this report. The stand and growth of clover in 1915 was poor, and the crop was left on the ground for the benefit of the succeeding corn crop. The crops of 1923, 1926 and 1936 were failures. In 1926, soybeans for hay were substituted.

Other plants have been included with the clover (red and alsike) as follows (year of harvest given) for the purpose of observation on adaptability to different conditions.

1916	Orchard grass and tall meadow oat grass
1917	Sweet clover and timothy
1918-19	Sweet clover
1921	Timothy
1925	Timothy
1926	Common lespedeza and timothy
1927	Common lespedeza, timothy and alfalfa
1928	Common and Korean lespedeza, timothy and alfalfa

Beginning with 1925, all additions have been retained to the present, except that common lespedeza was dropped, beginning with 1932, and alsike clover, beginning with 1935.

The crop yields for the various fertilizer treatments are given in Table 11. Second cuttings made in a year are included in the averages. The crop yields are given in two periods preceding the change in rotation. The yields in the changed rotation are given in a third period.

Residual Effect of Phosphates. Beginning in 1931, plots 6 (MLP), 8 (MLRp) and 9 (MLP) were divided when they came to wheat. On one half of each plot the phosphate treatment was continued, and on the other half it was discontinued (designated 6a, etc.). The average yields on the two halves of the plots were as follows:

All plots previously limed	Corn Average of 6 crops	Wheat Average of 8 crops	1st-year hay Average of 6 crops	2d-year hay Average of 6 crops
	bushels	bushels	pounds	pounds
Plot 6 Superphosphate continued	54.7	22.8	5187	4407
6a Superphosphate discontinued	52.7	20.6	4763	3963
Plot 8 Rock phosphate continued	55.3	23.7	5637	4517
8a Rock phosphate discontinued	54.6	23.5	5517	4555
Plot 9 Superphosphate continued	53.1	24.5	5720	4707
9a Superphosphate discontinued	54.1	21.7	5080	4627

Table 11. Average crop yields per acre, Mayfield Soil Experiment Field

Plot No.	Treatment*	Corn, bus., 23 crops					Soybean hay, lbs., 16 crops			
		First 9 crops	Next 9 crops	Last 5 crops	23 crops	Increase**	First 8 crops	Next 8 crops	16 crops	Increase
1	O	24.3	29.8	21.0	25.7	—8.2	1753	2019	1886	—409
2	ML	37.3	50.4	46.8	44.5	10.6	2926	2988	2957	662
3	M	28.1	38.8	35.8	33.9	.....	2211	2379	2295	.....
4	MP	28.3	44.2	41.2	37.3	2.1	2445	2583	2514	161
5	MRp	32.4	50.1	49.6	43.1	6.6	2650	3039	2844	433
6	MLP	41.0	56.2	52.2	49.4	11.7	3382	3413	3397	930
7	M	33.7	44.0	39.6	39.0	.....	2443	2609	2526	.....
8	MLRp	44.7	55.5	51.4	50.4	11.7	3588	3485	3536	944
9	MLP	40.7	52.7	50.2	47.5	9.1	3482	3603	3542	886
10	LP	36.3	39.2	32.7	36.7	—1.3	3317	3330	3323	602
11	M	31.6	40.9	43.0	37.7	.....	2581	2991	2786	.....
12	MK	31.5	40.5	41.4	37.2	—1.4	2556	2670	2613	—211
13	MLK	44.0	57.0	53.8	51.2	11.7	3673	3575	3624	762
14	MLPK	47.4	60.9	55.0	54.4	14.0	3917	3884	3900	999
15	M	35.6	45.4	44.0	41.3	.....	2734	3144	2939	.....
16	MLRpK	43.8	57.5	53.6	51.3	10.0	3663	3739	3701	762
17	MLPKN	41.4	58.3	54.6	50.9	9.6	3713	3914	3813	874

* O = no treatment, M = manure, L = limestone, P = superphosphate, Rp = rock phosphate, K = muriate of potash, N = nitrate of soda.

** Increases calculated upon the assumption that the soil varied uniformly between check plots before treatment.

(See page 322.)

Table 11 (Continued)

Plot No.	Treatment	Wheat, bus., 21 crops					1st-year hay, lbs., 19 crops					2d-year hay, lbs., 6 crops	
		First 7 crops	Next 7 crops	Last 7 crops	21 crops	Incr.	First 7 crops	Next 7 crops	Last 5 crops	19 crops	Incr.	Yield	Increase
1	O	6.0	5.0	5.2	5.4	—3.3	290	1697	2246	1323	—95	2243	—165
2	ML	11.8	13.7	14.8	13.4	4.7	2637	3280	3326	3055	1637	3487	1079
3	M	8.1	8.7	9.3	8.7	.....	574	1667	2252	1418	.....	2408	.....
4	MP	11.4	12.9	13.6	12.6	3.5	999	2846	3186	2255	733	2893	403
5	MRp	11.3	16.6	16.9	14.9	5.4	1826	4279	4710	3488	1862	4250	1677
6	MLP	17.5	22.2	20.5	20.1	10.1	3410	4907	5356	4474	2743	4407	1752
7	M	10.2	9.1	12.0	10.4	.....	817	2183	2774	1835	.....	2737	.....
8	MLRp	19.1	21.3	21.3	20.5	10.1	3513	4790	5924	4618	2698	4533	1743
9	MLP	18.6	25.8	21.9	22.1	11.7	3673	4967	6000	4762	2757	4707	1863
10	LP	17.1	21.1	18.8	19.0	8.6	3417	3696	4408	3781	1691	3997	1100
11	M	9.2	10.2	11.7	10.4	.....	1147	2566	3066	2175	.....	2950	.....
12	MK	12.1	10.3	12.0	11.5	1.1	1086	2226	2794	1955	—210	2647	—285
13	MLK	16.7	20.9	19.6	19.1	8.7	3361	4664	4212	4065	1910	4083	1169
14	MLPK	20.5	27.6	23.8	24.0	13.5	4394	6150	5996	5462	3316	4475	1580
15	M	9.7	11.0	10.7	10.5	.....	1462	2544	2506	2136	.....	2877	.....
16	MLRpK	13.8	21.4	19.3	18.2	7.7	3900	5406	5674	4922	2786	4563	1686
17	MLPKN	16.8	28.8	24.7	23.4	12.9	4157	5640	6346	5279	3143	5543	2666

Where both phosphates were used thruout the experiment, the ratio of phosphorus applied in twenty-six years in superphosphate and rock phosphate was 1 to 4. As between superphosphate continued and rock phosphate discontinued, the ratio for twenty-six years was approximately 1 to 3. (See page 323 for the relative prices of the two materials thru the period 1913–1938.)

Discussion of Results. The outstanding result in these experiments is the effect of limestone in increasing yields. It is the first limiting factor for all the crops of the rotation. Superphosphate without limestone was not very effective, but used with limestone it produces a good increase. On unlimed soil, rock phosphate was decidedly more effective than superphosphate at the rates used. Where used with limestone, they were about equally effective.

Potash appeared quite effective in some comparisons, but when all comparisons are considered the increase from its use was not significant. The effectiveness of manure as a carrier of potash is shown by comparison of plots 9 and 10. The two sets of plots were treated alike with limestone and phosphate. Beginning with 1916, the corn crop on plot set number 9 was manured as described on page 379. On plot set number 10 the cornstalks and wheat straw were returned to the corn ground thru 1916–19. Since then no manure or residues have been returned. An examination of the yields by periods (Table 11) shows a gradual decrease in yield on plots where manure was not returned. Decided symptoms of potash deficiency were present in the crops in the last period. In 1937 the yield of corn on plot 9 was 52.6 bushels, and on plot 10, 29.3 bushels. Part of plot 10 was fertilized liberally at the hill with potash, which brought the yield up to 52.1 bushels.

RECOMMENDATIONS ON SOIL MANAGEMENT AND FERTILIZER PRACTICES

1. **Cropping Systems.** A cropping system should be adopted which keeps as much of the land as possible occupied by grass and legume mixtures for pasture and hay. If sufficient nutritious pasture and hay are available, the amount of grain feed required will be much reduced. Pasture and hay produced

on impoverished soil are not as nutritious as if produced on a fertile soil, nor will pasture on impoverished soil furnish grazing for as long a period as that produced on fertile soil. It is therefore just as important to enrich land for pasture and hay as for grain crops and tobacco. The best way to prepare land for grain and tobacco is to enrich it thru grass and legumes for pasture and hay, with proper grazing and the conservation and use of manure.

One of the most important requirements for soil conservation is to reduce the tilled crop acreage. This can be done in two ways—first, by maintaining livestock more on pasture and hay, and second, by increasing the productivity of the tilled-crop land. The central Bluegrass region is an outstanding example of these practices. Here only about 25 percent or less of the plowable land is used for tilled crops like corn and tobacco. (See Kentucky Extension Circular 272 for directions for planning rotations.)

2. **Use of Manure, Crop Residues and Legumes.** All manure should be carefully saved. It is estimated that the farm manure produced in Kentucky is worth about $30,000,000 annually, at conservative valuation, and that 40 to 50 percent of it is wasted. All stalks, straw and other litter should be used as bedding to absorb the liquid excrement, which contains nearly half of the nitrogen and two thirds of the potash voided by animals. The stalks and straw of the grain crops contain about three fourths of the potash of the entire crop. It is apparent that if manure and residues are wasted, a potash shortage must sooner or later occur. Tobacco stalks contain large amounts of nitrogen and potash which are largely soluble in water. There is a very large wastage of plant food in tobacco stalks thru their exposure to rain before spreading. (See Kentucky Extension Circular 272 for information on crop residues and manure.)

None of the legumes will greatly increase the nitrogen content of medium to good soil unless they are pastured, left on the ground or fed and the manure made by feeding them returned to the soil. Where soybeans and cowpeas are removed from the soil without return of manure, the nitrogen content of the soil may be lowered. If the manure made from feeding them is returned, more nitrogen may be added to the soil than is with-

drawn. Usually manure is used most profitably on corn and tobacco land. All pasture-grass mixtures should contain legumes to meet the nitrogen needs of the grasses, and all legumes should have grass with them to conserve the nitrogen fixed by the legumes. (See Bulletin 374 for information on legumes in cropping systems.)

3. **The Use of Liming Materials.** Most of the soils of the state need liming. Some exceptions are found in the hill region of northern Kentucky and in the vicinity of marl deposits. On most of the acid soils of the state, yields of the so-called acid-tolerant legumes, soybeans, cowpeas and lespedeza, usually are increased profitably by the use of lime.

Some of the most acid soils of the state are found in the region of the black shale knobs surrounding the Central Bluegrass area, in the shale and sandstone area on the western border of the Eastern Coal Field, and in some of the uplands of the "Purchase" area. Soils of limestone origin are generally acid unless they contain fragments of limestone or lie below marl deposits from which marl is carried onto them.

Soils of moderate acidity generally respond to liming, as is shown by the results on the Campbellsville and other experiment fields. An initial application of 1 to 2 tons of limestone per acre is sufficient for most of the acid soils of the state. Where rock phosphate is to be used, not more than 2 tons per acre should be applied. A minimum of 2 tons is recommended for alfalfa, and 3 to 4 tons will likely prove profitable on the more acid soils. Reliming should be done only when there is evidence of the need of it. On most of the soils of the state a 2-ton application will be effective for eight to ten years or more. A good way to determine the need for reliming is to relime a small area preceding each legume crop and note the effect.

On most of the soils of the state outside the Bluegrass area, lime without a phosphate fertilizer has not been very effective. An exception is the soil represented by the Mayfield Experiment Field. However, here it was profitable to use the combination.

On land on which tobacco is to be grown, only moderate applications of a liming material should be used, and it should be applied as far in advance of the tobacco crop as possible, not immediately before it. There is no evidence in any of the

experimental work of the Experiment Station that liming directly benefits tobacco; in fact there is evidence of lowering of yield and evidence of injury to quality by liming too heavily. This experience should not deter farmers from using liming materials on tobacco land, but should be cause for care as to the amount used and the method of using it. There is much evidence of improvement of tobacco from liming at a moderate rate thru its effect on legumes in the rotation. Where too much lime has been used on tobacco land, its injurious effects may be overcome to some extent by liberal fertilization with high-grade complete fertilizer. (See Bulletin 379 for soil management and fertilizer practices for tobacco.)

Where liming materials are expensive on account of long haul or other causes, it is recommended that a mixture of two parts of ground limestone or hydrated lime and one part of superphosphate or other fertilizer containing a liberal amount of phosphate be drilled in with small grain at the maximum capacity of the drill. This should greatly benefit the clover and grass mixtures sown on the small grain. The mixture should first be tried on a small scale. The practice is giving excellent results in many parts of the state. It is especially recommended on land on which tobacco is to be grown. It will be necessary to repeat the treatment before each legume crop for a few years. The plan has the merit of enabling the farmer to grow legumes on a large area with a small outlay for liming materials. Burned lime and hydrated lime should not be mixed with fertilizers containing ammonium salts.

Many county agents are prepared to test soil for lime and phosphorus needs and are glad to render the service.

4. **The Use of Phosphate Fertilizers.** In the experiments outside the Bluegrass area, phosphate fertilizers have been effective on both limed and unlimed soil on all the outlying fields except that at Mayfield superphosphate was not very effective on unlimed ground.

It is suggested that 300 to 400 pounds per acre of superphosphate or its equivalent of other phosphate fertilizer be used on the small-grain crop on which will be sown a legume and grass mixture of the character desired for hay or pasture. Much land in the state is so slightly acid that fairly good yields of clover

of adapted strains and other legumes can be grown without liming, if phosphate fertilizers are used liberally.

On the Campbellsville and Fariston fields the use of limestone with rock phosphate resulted in smaller yields in the earlier years of the experiments than the use of rock phosphate alone. These soils were limed heavier than was necessary, but it was not known to be so at the time they were limed. On all the outlying experiment fields, rock phosphate was generally as effective on unlimed soil as half its weight of superphosphate, or more so. On none of the fields was rock phosphate more effective on limed soil in the earlier years of the experiment than half its weight of superphosphate. It will be noted that in the last period, on most of the fields, the effectiveness of rock phosphate in comparison with superphosphate on limed ground has increased, and that in some cases it has gone ahead of superphosphate. Steamed bone meal (at Fariston) and basic slag (at Campbellsville) were both found to be effective sources of phosphorus. Where rock phosphate is used, it is recommended that enough be applied at one time to serve for a rotation (600 to 1,000 pounds per acre) and that it be thoroly incorporated with the soil in preparing the land for small grain with which legumes and grasses are to be sown. If grain is to be harvested, it would be well to drill with the grain a light application of superphosphate for its effect on grain yield. Land on which rock phosphate is to be used should not be limed heavily—one to two tons per acre is usually sufficient. Heavy liming reduces the effectiveness of rock phosphate on some soils.

5. **The Use of Complete Fertilizers on Grain and Hay Crops.** If a phosphate fertilizer has been used for grass and clover as recommended in number 4 and manure is applied when the sod is broken, a moderate application of a phosphate fertilizer usually is sufficient for corn or other crops except tobacco. It would perhaps be better to use enough phosphate for the grain and grass crops to leave a reserve sufficient for corn, when manure is used. (See pages 345-6). However, there may be soil conditions for which a complete fertilizer or a phosphate-potash fertilizer will be more profitable than a phosphate fertilizer. The following tests are suggested: For corn, compare 100 to 150 pounds of superphosphate or its equivalent of other phosphate

fertilizer, per acre, in the hill or row, with a fertilizer containing not less than 4 percent of nitrogen, 10 to 12 percent of phosphoric acid, and 6 to 8 percent of potash. Use enough of the latter fertilizer to supply the same amount of phosphoric acid as in the amount of phosphate used. The same fertilizer analysis, leaving out the nitrogen, might be compared with the phosphate. If preferred, these comparisons may be made on the basis of equal money values of the fertilizers used. Tests of this kind are a better basis for fertilizer usage than a chemical test of the soil. These comparative tests should be repeated a few years before adopting any one of the treatments as a regular practice. The same comparisons of fertilizers may be tried on small grain and the clover and grass sown with it, using 300 to 400 pounds of superphosphate per acre as a basis. Any soil of this state will sooner or later show a potash deficiency if crops are removed without a careful saving and utilization of crop residues and manure.

For the row crops, moderate applications of fertilizers, say up to 250 pounds per acre, of the ordinary kinds, are generally more effective in the hill or row than broadcast. Hill applications should be thoroly mixed with the soil or, better, placed in bands on each side of the plant, as is done by some modern fertilizer drills.

It should be kept in mind that the small amount of complete fertilizer commonly used in the hill or row for corn and small grain furnishes only a small part of the needs of the crop for nitrogen and potash, and that, at present prices of crops and fertilizers, the main supply of these elements is best maintained by the production and proper use of legumes and manure.

6. **Fertilizing Alfalfa.** On all soils of the state except the high-phosphorus soils of the Central Bluegrass area, alfalfa should be liberally fertilized with phosphate. Alfalfa is a heavy feeder on potash and requires a large amount in a short period of growth, and unless the land is liberally manured or potash fertilizer is used, a deficiency of this element is very apt to occur. In all seedings of alfalfa it is recommended that a test be made for the need of potash. This may be done by applying muriate of potash at the rate of 200 pounds per acre on a plot that has been limed and liberally fertilized with a phosphate

fertilizer. If potash shows beneficial effects, the remainder of the crop may be top-dressed immediately following a cutting.

Alfalfa makes such a heavy draft on the soil that it often needs topdressing with fertilizers unless very large amounts were applied at seeding time. After the stand is two to three years old, or whenever it does not appear vigorous, it is advisable to make a top-dressing test by applying superphosphate (500 pounds per acre) on a small area, and superphosphate and muriate of potash (500 and 200 pounds per acre, respectively) on an adjoining area. If either treatment increases yield sufficiently, the remainder of the field may be treated accordingly. These tests are best made before spring growth begins or immediately after the first cutting of the season.

When alfalfa is sown for the first time on soil that is deficient in nitrogen, a moderate application of a soluble nitrogen fertilizer may be helpful in supporting the crop until inoculation becomes effective. An application supplying 15 to 20 pounds of nitrogen per acre is suggested for this purpose.

7. **Top-dressing.** Top-dressing with soluble nitrogen fertilizers is profitable under some conditions, for small grain, timothy for hay, bluegrass and orchard grass for seed, and pasture. The prices of crops and fertilizer materials will be large factors in the profitableness of the practice. The use of nitrogen top-dressings is most likely to be profitable in backward springs and on thin land, but is not likely to be profitable except on land well supplied with phosphorus and potassium, either naturally or by application.

Pastures that have not been liberally treated with phosphate may respond profitably to top-dressing with phosphate. A test may be made by using 300 to 500 pounds per acre of superphosphate, or an equivalent of other phosphate, on a small area and observing the results. Top-dressings should be made when the herbage is dry. As a precaution against possible injury, livestock may be kept off top-dressed pasture until rain has washed adhering fertilizer from the herbage.

8. For recommendations for fertilizing tobacco, see Bulletin 379 or Kentucky Extension Circular 230.

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KENTUCKY
AGRICULTURAL EXPERIMENT STATION
University of Kentucky
THOMAS P. COOPER, Dean and Director

STANDARD STRAINS OF SALMONELLA

By P. R. EDWARDS

The Department of Animal Pathology of the Kentucky Agricultural Experiment Station has been designated as a National Salmonella Center by the International Salmonella Center at the State Serum Institute, Copenhagen, Denmark. The international center, which was established thru the cooperation of the Commonwealth Fund, is under the direction of Dr. T. Madsen and Dr. F. Kauffmann. Its purpose is to stimulate the study of organisms of the genus Salmonella, to assist in the identification of cultures and to serve as a repository of standard strains.

National centers have been established in a number of countries and to these centers have been sent standard cultures and diagnostic serums. It is the duty of the national centers to identify Salmonella cultures sent to them from other laboratories and to supply interested workers with standard strains to be used for comparison.

The department will now undertake the identification of cultures of the genus Salmonella which are submitted to it for study. Further, it is ready to supply standard strains to laboratories wishing to specialize in the study of the genus. These cultures were received from the International Salmonella Center as authentic representatives of the various serologic types.

The index numbers, identity and antigenic formulae of the cultures are as follows:

	Cultures	O-Antigen	H-Antigen 1. phase	H-Antigen 2. phase
1	S. paratyphi A 1015	I.II	a	—
2	S. paratyphi A var. durazzo	II.	a	—
3	S. paratyphi B 8006	IV.V.	b	1,2...
4	S. paratyphi B 6617	I.IV.V.	b	1,2...
5	S. paratyphi B var. java	IV.V.	b	—
6	S. paratyphi B 5706 (chiefly non-spec.)	IV.V.	[b]	1,2...
7	S. paratyphi B var. odense 8085	IV.	b	1,2...
8	S. paratyphi B var. odense 9864	I.IV.	b	1,2...
9	S. typhi murium 1406	IV.V.	i	1,2...
10	S. typhi murium 4066	I.IV.V.	i	1,2...
11	S. typhi murium var. copenhagen 659	IV.	i	1,2...
12	S. typhi murium var. copenhagen 3146	I.IV.	i	1,2...
13	S. typhi murium (O-form) 3173	IV.V.	—	—
14	S. typhi murium (chiefly non-spec.) 10953	IV.V.	[i]	1,2...
15	S. stanley 7855	IV.V.	d	1,2...
16	S. heidelberg	IV.V.	r	1,2...
17	S. chester	IV.V.	e,h	e,n,x
18	S. chester 1254	IV.	e,h	e,n,x
19	S. reading	IV.	e,h	1,5...
20	S. derby 31	IV.	f,g...	—
21	S. derby 15145	I.IV.	f,g...	—
22	S. essen 173	IV.	g,m...	—
23	S. budapest	IV.	g,t...	—
24	S. brandenburg 647	IV.	l,v	e,n
25	S. bispebjerg 9447	IV.	a	e,n,x
26	S. abortus equi β 202	IV.	—	e,n,x
27	S. abortus ovis 4195	IV.	c	1,6...
28	S. abortus bovis α 1960	I.IV. +	b	[e,n,x]
29	S. abortus bovis β 1960	I.IV. +	[b]	e,n,x
30	S. bredeney 1051	I.IV. +	l,v	1,7...
31	S. schleissheim α 13	IV. +	b	—
32	S. paratyphi C (Vi+) "East Africa"	VI.VII. Vi	c	1,5...
33	S. paratyphi C (Vi—) "Hirschfeld"	VI.VII.	c	1.5...
34	S. cholerae suis 1348	VI.VII.	c	1,5...

Cultures	O-Antigen	H-Antigen 1. phase	H-Antigen 2. phase
35 S. cholerae suis 1535 spec. rough	—	c	—
36 S. cholerae suis var. kunzendorf 1350	VI_1.VII.	—	1,5...
37 S. cholerae suis var. kunzendorf 5210	VI_2.VII.	—	1,5...
38 S. typhi suis 1347	VI.VII.	c	1,5...
39 S. thompson 8	VI.VII.	k	1,5...
40 S. thompson var. berlin 2988	VI.VII.	—	1,5...
41 S. virchow 4519	VI.VII.	r	1,2...
42 S. oranienburg 9087	VI.VII.	m,t...	—
43 S. potsdam 9781	VI.VII.	l,v	e,n
44 S. bareilly 3213	VI.VII.	y	1,5...
45 S. mikawashima 56	VI.VII.	y	e,n
46 S. montevideo 623	VI.VII.	g,m,s...	—
47 S. oslo	VI.VII.	a	e,n,x
48 S. amersfoort	VI.VII.	d	e,n,x
49 S. braenderup 3022	VI.VII.	e,h	e,n
50 S. newport 563	VI.VIII.	e,h	1,2...
51 S. newport var. puerto rico	VI.VIII.	—	1,2...
52 S. kottbus 4179	VI.VIII.	e,h	1,5...
53 S. bovis morbificans 3640	VI.VIII.	r	1,5...
54 S. muenchen	VI.VIII.	d	1,2...
55 S. narashino	VI.VIII.	a	e,n,x
56 S. glostrup 4324	VI.VIII.	z_{10}	e,n
57 S. typhi H 901 W	IX.	d	—
58 S. typhi O 901 W	IX.	—	—
59 S. typhi 2 V	IX. Vi	d	—
60 S. typhi Watson V	IX. Vi	d	—
61 S. typhi 6 S	Vi	[d]	—
62 S. typhi Vi 1	(IX.) Vi	[d]	—
63 S. typhi R_2 rough	—	d	—
64 S. enteritidis 1891	IX.	g,m...	—
65 S. dublin 215	IX.	g,p...	—
66 S. rostock	IX.	g,p,u...	—
67 S. moscow 27	IX.	g,q...	—
68 S. blegdam 22	IX.	g,m,q...	—

	Cultures	O-Antigen	H-Antigen 1. phase	H-Antigen 2. phase
69	S. berta	IX.	f,g,t...	—
70	S. eastbourne	IX.	e,h	1,5...
71	S. sendai 571	I.IX.	a	1,5...
72	S. dar es salaam	I.IX.	l,w	e,n
73	S. panama	I.IX.	l,v	1,5...
74	S. gallinarum 416	IX.	—	—
75	S. pullorum 971	IX.	—	—
76	S. london 1446	III.X.XXVI.	l,v	1,6...
77	S. give 316	III.X.XXVI.	l,v	1,7...
78	S. anatum 293	III.X.XXVI.	e,h	1,6...
79	S. muenster 4546	III.X.XXVI.	e,h	1,5...
80	S. nyborg 1527	III.X.XXVI.	e,h	1,7...
81	S. amager 2399	III.X.XXVI.	y	1,2...
82	S. zanzibar 5628	III.X.XXVI.	k	1,5...
83	S. shangani 5630	III.X.XXVI.	d	1,5...
84	S. newington C_2	III.XV.	e,h	1,6...
85	S. selandia 7482	III.XV.	e,h	1,7...
86	S. new brunswick 5411	III.XV.	l,v	1,7...
87	S. senftenberg 3007	I.III.XIX.	g,s,t...	—
88	S. niloese 1236	I.III.XIX.	d	z_6...
89	S. tim 1928	III.XV.	e,h...	1,6...
90	S. aberdeen	XI.	i	1,2...
91	S. poona	XIII.XXII.	z...	1,6...
92	S. worthington 29	I.XIII.XXIII	l,w	z...
93	S. carrau 34	VI.XIV.XXIV	y	1,7...
94	S. onderstepoort 282	(I).VI.XIV.XXV.	e,h	1,5...
95	S. hvittingfoss	XVI.	b	e,n,x
96	S. gaminara 974	XVI.	d	1,7...
97	S. kirkee	XVII.	b	1,2...
98	S. kentucky 21883	(VIII).XX.	i	z_6...
99	S. minnesota 21	XXI.XXVI.	b	e,n,x
100	S. cerro 415	XVIII.	z_4	—

( ) indicates that only a fraction of the O-Antigen is present
[ ] indicates that these antigens may not appear